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Science and Intertext:
Methodological Change and Continuity in Hellenistic Science

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Science and Intertext:
Methodological Change and Continuity in Hellenistic Science

by

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Dedication

for my parents

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This dissertation investigates the appropriation of material from one scientific field into another in the early Hellenistic period, 300-150 BCE. Appropriation from one science into another led to the emergence of new concepts in a community of scientists. Herophilus of Chalcedon's appropriation of musical rhythms led to the emergence of the pulse as a materio-semiotic object for Rationalist physicians. Archimedes of Syracuse's appropriation of mechanical concepts of weighing led to the emergence of the mechanical method as a scientific way of seeing for practicing mathematicians. But objects and concepts emerging from cross-scientific appropriation had ideological consequences for scientific methodology within individual scientific communities. Archimedes prioritized a formal Euclidean proof over that offered by the mechanical method because of the standards of proof demanded by the community of practicing mathematicians. The sect of Empiricist physicians rejected Rationalist medicine and promoted the individual doctor's role and authority as a medical caregiver. The dissertation's sum tells a story of

increasing but limited strategies of naturalization within the sciences of the early Hellenistic period.

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Chapter 1: Introduction and Theoretical Overview

This chapter introduces the study of cross-field scientific activity in the early Hellenistic period. It provides a critique of G.E.R. Lloyd's work on this topic and offers hope for an analysis of cross-scientific work in terms of comparative sociology. An overview of the theoretical grounding of this dissertation follows: theories of intertextuality and the semiotic study of science developed by sociologist Bruno Latour.

1.1 The Problem of Cross-Field Scientific Activity

The arteries pulsing in looped beats. Parabolas hung and sliced and weighed on a balance. The divination sieve of the natural numbers. These are not the images of ancient Greek science that first come to mind. Yet all these examples come from Greek science produced in the third century BCE, by the leading doctors and mathematicians of the age.[1] All these examples involve one domain of scientific activity – the physiology of vascular tissue, the calculation of area, the sequence of prime numbers – placed and analyzed within the compass of another scientific field – music, mechanics, astrology.[2]

What motivated successful Greek scientists in the Hellenistic period to adopt cross-field strategies for interpreting the natural world? After all, the various Greek sciences by 300 BCE had at least 120-150 years, if not more, of analysis with their own traditions to draw upon. Medicine had developed *qua* medicine, mathematics *qua* mathematics.[3] They were separate fields with internally driven standards of argumentation. To a great extent, works such as the Hippocratic *Ancient Medicine* and *On the Sacred Disease* and mathematical treatises by Eudoxus had laid out acceptable

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[1] The examples are from, respectively, Herophilus, Archimedes, and Eratosthenes. The first two examples are discussed in chapters 2 and 3; see Netz (2009a: 150.n24) for Eratosthenes' sieve as an appropriation of astrology.

[2] The crossing of scientific domains (as I will call the separate traditions of the sciences below) in the Hellenistic period are not the mixed sciences known from Aristotle's philosophy of science, in which physical sciences are subordinate to mathematical principles, such as optics or meteorology. For the mixed sciences see Lennox (1985: 39-49).

[3] The consequence of Lloyd's (1991b) thesis is that one speaks more appropriately of 'sciences' in the Classical period than 'science'.

strategies of argumentation within particular sciences.[4] Doctors should not engage in unsubstantiated hypotheticals, especially involving supernatural forces; mathematicians demanded a formal deductive proof. But the above examples of arterial pulsation, balanced parabolas, and a divination sieve for numbers violate these traditional criteria for argumentation. How could a scientist reject traditional criteria of argumentation and still hope to present a successful argument to others in his field? How could a doctor present to other doctors medical arguments that were described and analyzed by the theories and standards of musicians? The intellectual success and subsequent fame of the Hellenistic scientists who employ non-traditional analysis suggests that these examples of cross-field scientific activity are not freakish coincidences.[5] This dissertation will argue that the scientific strategies involved in all these examples are part of a cultural pattern common to Greek science of the Hellenistic period.

I use the word 'science' to indicate the production of knowledge involving the theoretical investigation of the natural world and the practical application of knowledge drawn from that theoretical investigation. This definition is adopted from modern sociological studies of science.[6] In the following pages I will use the term 'science' to indicate both the production of knowledge and the group of individual fields concerned with natural investigation, I will use the term 'scientist' to refer to the individuals whose work concerned at least one field of natural investigation, and I will use the term 'scientific' to describe the field of natural investigation and the community of individuals concerned with natural investigation. I eschew terms anachronistic to Hellenistic period thought such as 'natural philosopher', 'scientific method', and 'scientism'. The terms 'science', 'scientists' and 'scientific' are largely confined to chapters 1 and 5; the terms for the individual sciences and their practitioners replace them in chapters 2-4.

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[4] See Flemming (2000: 80-122) on further division within medicine.

[5] Berryman (2009) argues that mechanical metaphors and technological illustration are common in Greek philosophical and scientific thought, particularly in the Hellenistic period. See also Barton (1994b) on astrology, physiognomics, and medicine as prognostic sciences of the Imperial period.

[6] See Barnes, Bloor, Henry (1996: 113): "As far as the specific project of sociology of science is concerned, to describe science according to the normal sociological model is to treat it the same as knowledgeable activities in other social contexts."

Is it appropriate to talk of 'science' within Hellenistic Greek thought? No single ancient Greek word equates precisely to the modern Western concept of 'science'. Greek investigators into nature variously speak of their investigation as ἐπιστήμη or θεωρία – terms stressing "knowledge" – or τέχνη, a term emphasizing skill in "practice" or "craft"; they typically speak of the object of their investigation as φύσις, "natural order".[7] It is a conclusion of this study that some category of 'science' did exist in Greek thought of the Hellenistic period, although the full argument must wait until chapter 5, the concluding chapter.[8] For now let it suffice to underscore two claims: first, that *some* Hellenistic Greeks had a category of 'naturalized' *physis* which crossed several knowledge domains and, second, that, although they had no word for it, Hellenistic Greeks had a concept of knowledge production that perceived connections between different areas of *physis* . Both these claims allow to some degree the application of models drawn from contemporary sociology of science to a knowledge production culturally-specific to the Hellenistic world.

Science by the above sociological definition includes fields such as theoretical mathematics, applied mechanics, medicine, astronomy, and astrology, among others; these are our terms for knowledge production. In the Hellenistic world knowledge production was known under various Greek terms such as μαθήματα, μηχανικά, ἰατρική, ἀστρολογικά, and so on. For the most part these Greek terms correspond to their translations in modern scientific domains, but in some cases there is not a complete mapping of ancient to modern. For instance, to speak of ἀστρολογικά is to speak with historical actors' terms; to speak without qualification of 'astronomy' or 'astrology' is to privilege our observers' terms.[9] Knowledge production over a certain area is defined within a cultural framework: ἀστρολογικά by the above sociological definition is knowledge production involving the stars culturally-specific to the ancient Greeks, namely, the stars' distances from each other and from earth, and their powers over life,

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[7] See LSJ ἐπιστήμη II.2; LSJ θεωρία III.2.b; LSJ τέχνη III; LSJ φύσις III.

[8] Chapter 5.1-2 discusses the methodological choices of historians of science during the Greco-Roman period for or against the English term 'science' and its derivatives.

[9] See Lloyd (1992) for the anthropological distinction between actors' and observers' terms.

health, and character on earth. It may be an open scholarly question to what extent the domains of the terms 'astronomy' and 'astrology' (knowledge production terms specific to *our* culture) were seen as united or different in Greco-Roman antiquity, but it is not disputed that ἀστρολογικά as a knowledge production concerning the stars was considered a 'science' within *their* culture.

The study of the sciences in the Hellenistic world is not limited to the production of knowledge in various domains. Philip van der Eijk (2005b) has described the study of medicine in ancient Greece in a way that encompasses the many cultural and social aspects of that particular science:

> The focus of medical history is on the question of how society and its individuals respond to pathological phenomena such as disease, pain, death, how it 'constructs' these phenomena and how it contextualises them, what it recognises as pathological in the first place, what it labels as a disease or aberration, as a epidemic disease, as mental illness, and so on. How do such responses translate in social, cultural and institutional terms: how is a 'healthcare system' organised? What status do the practitioners or 'providers' of treatment enjoy? How do they arrive at their views, theories and practices? How do they communicate these to their colleagues and wider audiences, and what rhetorical and argumentative techniques do they use in order to persuade their colleagues and their customers of the preferability of their own approach as opposed to that of their rivals? How is authority established and maintained, and how are claims to competence justified?[10]

In van der Eijk's view, medical historians investigate how society constructs phenomena of pain and disease and how such responses are translated in cultural terms. In this formulation science is part of the 'discourse' of culture and analyzable as such. Science in the Greek world is thus one of the many activities and cultural productions that Greeks engaged in.

My study embraces the notion of science as a cultural activity as well as knowledge production. I use the many elements of cultural analysis – cultural discursivity, sociological analysis – to understand the development and spread of science in Hellenistic Greece. Indeed, the notion of traditional criteria in scientific argumentation

[10] Van der Eijk (2005b: 6).

that I sketched above is fundamentally a sociological notion. The Euclidean deductive proof, for example, is a standard of argumentation embraced by the Hellenistic community of mathematicians: no other type of argumentation – e.g. appeal to authority, illustrative diagrams, mechanical analysis – was sufficient on its own for the community of practicing mathematicians to accept the conclusion reached. To speak of standards of proof and argumentation is to speak sociologically, in terms of the shared agreement of the scientific community.

This dissertation will focus on cross-field appropriations between the sciences in the early Hellenistic period, roughly c. 300-150 BCE. The heart of my analysis is a series of three case studies: chapter 2, Herophilus of Chalcedon's analysis of the pulse in terms of musical rhythms; chapter 3, Archimedes of Syracuse's treatise *Ephodos* which analyzes mathematical objects by weighing them on an imaginary balance; and chapter 4, the debate between the rival medical schools of Empiricist and Rationalist physicians in the 3rd and 2nd centuries BCE. I am interested above all in the how and why of the interaction of the sciences across fields.

This study is therefore partly concerned with the emergence of new objects and concepts into a particular community of scientists.[11] Emergence is a coming-to-be, innovation, discovery – in short, the label of newness. The new concepts and objects within one science can develop from the appropriation of materials and ideas from another science. In chapter 2 Herophilus' appropriation of musical rhythm will lead to

[11] Daston (2000: 13) similarly describes ontology revived for scientific historians: "Reality for scientific objects instead expands into a continuum, just as degrees of probability opened up between the poles of true and false in seventeenth-century philosophy. Scientific objects may not be invented, but they grow more richly real as they become entangled in webs of cultural significance, material practices, and theoretical derivations. In contrast to quotidian objects, scientific objects broaden and deepen: they become ever more widely connected to other phenomena, and at the same time yield ever more layers of hidden structure. The sciences are fertile in new objects, and the objects in turn are fertile in new techniques, differentiations and associations, representations, empirical and conceptual revelations. The participle [sic] 'in the becoming' is a more than quaint rendering of Aristotle's Greek (*genesis*). It captures the distinctly generative, processual sense of the reality of scientific objects, as opposed to the quotidian objects that simply are. But what can be ontologically enriched can be also be impoverished; scientific objects can pass away as well as come into being. Sometimes they are banished totally from the realm of the real, as in the case of unicorns, phlogiston, and the ether. More often, they slip back into the wan reality of quotidian objects, which exist but do not thicken and quicken with inquiry."

the emergence of a materio-semiotic object, the pulse. In chapter 3 Archimedes' appropriation of mechanical tools will lead to the emergence of a scientific way of seeing, the mechanical method. Cross-scientific appropriation led to new objects and concepts within a particular scientific community.

How scientists appropriate theoretical material from different fields will be indicative of a particular scientific community's willingness to accept standards of argument and proof different from their own traditional standards. While my argument focuses on the standards of the medical and mathematical communities, I do not believe that these trends are unique to mathematics and medicine; I intend it to be considered within the context of studies of all sciences in the Hellenistic world. Chapter 2 considers how Herophilus' appropriation of musical theories of rhythm successfully provides a new ideology to the Greek medical community; chapter 4 considers how the debate between competing medical sects demonstrates the limits of acceptance of new standards within the medical community. Chapter 3 on Archimedes' treatise *Ephodos* is a case of both the emergence of a new mathematical way of seeing and a demonstration of the limited acceptance of cross-scientific appropriation within the mathematical community. The dissertation's sum total tells a story of increasing but limited strategies of naturalization within the sciences of the early Hellenistic period.

1.2 LLOYD'S GREEK SCIENCE

The study of cross-field scientific activity in the Hellenistic period is not wholly new territory. G.E.R. Lloyd has written on some of this material and Lloyd's work is central for a historical understanding of the aims and practices of Greek scientists. Lloyd's (1991) *Methods and Problems in Greek Science*, a collection of earlier essays, strongly attacked a stationary concept of Greek science in favor of individual problems in individual sciences. His later work continued this line of investigation, concentrating on the biological, zoological, and medical fields in *Science, Folklore and Ideology* (1983) and optics, acoustics, and physics in *The Revolutions of Wisdom* (1987). He proposed that Greek scientists worked in a highly competitive atmosphere that promoted individual polemics against their predecessors and sometimes contemporaries. He further proposed

that, in spite of competition, scientists usually tended to privilege individual results using common methods of inquiry rather than innovate new methods.[12]

Lloyd's work has had the salutary effect that scholars no longer speak in broad and overly-generalized terms about Greek science but now emphasize the diversity of opinions on scientific questions in various fields. As a consequence Lloyd's work has had the effect of promoting the study of individual sciences alone, with lesser attention to the wider contemporary scientific context, so that connections between fields are neglected.[13] In this introduction I will consider Lloyd's work against the case studies developed in later chapters in order to argue first in 1.2.1 that the methodological aim of Hellenistic Greek science is not always greater certainty and second in 1.2.2 that Lloyd's thesis cannot encompass a reading of Hellenistic scientific methodology which promotes some other aim at the expense of a formalist justificatory methodology. To do so I first present a short summary of my arguments of chapters 3 and 4.[14]

In chapter 3 I argue that Archimedes' *Ephodos*[15] both presents an innovative mathematical argument and yet rejects the conclusiveness of that argument. The treatise presents an innovative kind of mathematical argument about the area and volume of geometrical objects involving their decomposition into infinite sets of constituent line segments and their weighing around their centers of weight; in modern scholarship this argument is commonly known as the mechanical method.[16] Nevertheless, Archimedes claims that the mechanical method is insufficient as a formal proof, that is, the new argument is not conducted in the manner of the Hellenistic mathematical community's

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[12] See further contextualization of Lloyd in Barton (1994b: 11-12).

[13] Daston (2009) notes the trend of ever-more specialized monographs in the discipline of the history of science. Naturally, the better historically contextualized a treatment is, the more narrow and specialized it appears. To his credit Lloyd's scholarship actively seeks breadth in addition to specialization.

[14] Since in chapter 2.1.1 I show that the aim of Herophilus' pulse theory is greater certainty about *physis* in accordance with Lloyd's claims, I do not consider chapter 2 here.

[15] I refer to this treatise as *Ephodos*, conventionally called *Method*, for reasons described in 3.1.1.

[16] Dijksterhuis (1987: 313-22).

standard Euclidean proof. (The mechanical method is also not an acceptable mathematical proof according to contemporary twenty-first century CE mathematics.[17])

> [T]τοῦτο δὴ διὰ μὲν τῶν νῦν εἰρημένων οὐκ ἀποδέδεικται, ἔμφασιν δέ τινα πεποίηκε τὸ συμπέρασμα ἀληθὲς εἶμεν· διόπερ ἁμὲς ὁρῶντες μὲν οὐκ ἀποδεδειγμένον, ὑπονοέοντες δὲ τὸ συμπέρασμα ἀληθὲς εἶμεν, <ἐ>τάξομες τὰν γεωμετρεομέναν ἀπόδειξιν ἐξευρόντες αὐτοὶ τὰν ἐ<κ>δοθεῖσαν πρότερον.
>
> So this was not proven by what was now said but still creates a certain impression that the conclusion is true. Wherefore I, seeing that <the conclusion> is not proven but nonetheless suspecting that the conclusion is true, will test [it] in respect to the geometrized proof, which was published earlier after I myself discovered it.[18]

Archimedes gives priority to the formalized Euclidean proof, "the geometrized proof", over the proof offered by the mechanical method, "So this was not proven but still creates a certain impression that the conclusion is true": Archimedes justifies his rejection by a hierarchy of the formalization of proof. Archimedes seems to have not provided a formal proof for his most sensational mathematical results in the *Ephodos*, namely the volume encompassed by two intersecting cylinders and the volume encompassed by a cylinder and a certain planar parabola inscribed in a square prism. The treatise argues in the mechanical fashion and leaves each problem with the result attained via the mechanical method, with no formal proof appended (although such a proof is possible).

In chapter 4 I argue that the Empiricists and Rationalists, two competing medical sects (αἱρέσεις), attack each other for asymmetrical reasons. The Rationalists attack the

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[17] Deductive proof was, for the most part, the priority for Greek mathematics. This does not imply, however, that the foundations of Greek mathematics are still accepted today by professional mathematicians. While there are still some acceptable uses for Euclidean geometry in contemporary mathematics, modern mathematicians consider Greek Euclidean geometry logically incomplete and limited by naïve intuitions about geometric space and mathematical sets; see for example Mueller's (1981) critique of Greek standards of geometric proof set out in chapter 3.3.1. Although it is an exaggeration to say that modern mathematicians consider ancient Greek Euclidean geometry as equally suspect as modern doctors consider ancient Greek humoral theory, we must remember that ancient Greek mathematics and medicine are historical sciences with aims and methodologies different from our own sciences. The reader should not infer that any ancient scientific result or methodology is accepted by the modern scientific community.

[18] I print the text from Appendix B, Archimedes *Ephodos* lines 276-85. All translations are mine unless otherwise noted. My translation practice distinguishes between nouns and adjectives implied by the grammatical gender but unexpressed by the Greek text, which I mark by the angular brackets < >, and other words unexpressed by the Greek text but necessary in English translation, which I mark by the square brackets [ ].

Empiricists for their rejection of causality and dissection and anatomical knowledge; the Empiricists on the other hand attack the Rationalists for ignoring the person of the patient and the personalization of the healing arts. What was an argument about knowledge and reason for the Rationalists was for the Empiricists instead an argument about the role of the practitioner of medical science. The Empiricists rejected Rationalist dissection and other elements of new medical research for both epistemological reasons – the 'knowledge' gained from dissection is founded on a category error between living and dead – and for cultural reasons – the research scientist did not fill the role of traditional medical caregiver.

1.2.1 The Rejection of Innovation

My thesis, then, in the present section is that conclusions from these case studies show that Lloyd's reading of Greek science cannot account for cross-field activity in Hellenistic science whose methodological aim is *not* greater certainty. I contend that Archimedes' rejection of the mechanically devised style of argument and the Empiricist reassertion of the healing role of the physician against the Rationalist ought to be seen as culturally similar phenomena: they both concern the rejection of an innovative methodological approach in science for a more traditional approach. There are two levels at which to consider the phenomena: first at the level of each science, mathematics and medicine, and second at the level of the science as a cultural paradigm.

Since in antiquity mathematics held a social claim to greater certainty than the other sciences and the certainty mathematics offers is central to Lloyd's claims, I consider first the mathematical methodology of Archimedes' *Ephodos*. In the *Ephodos* Archimedes valued the formal Euclidean proof above mechanical arguments. Knorr (1986), discussing late ancient mathematical commentators who reject earlier solutions that are based on assumptions foreign to Euclid's methods, proposed a general solution about the classification of mathematical modes of argument and construction:

> The explicit restriction to one or another mode of construction is by its nature primarily a formal move, motivated by the urge to divide and classify the

> collected body of established results. Until the geometric corpus had attained a size and diversity meriting such efforts, there could hardly be much sense in engaging in these formal enquiries.[19]

While it is unclear whether in Archimedes' lifetime the geometric corpus included enough results to separate and classify them by construction method, Knorr's important point is the idea of the development of mathematics. Knorr proposes to see the logical moves of formal classification as a historical and not a technical issue, consequently demanding a historical solution. If we were to apply Knorr's argument to Archimedes' *Ephodos*, we would see a scientist attempting to classify proper and improper solutions. But we ought to reject the applicability of Knorr's argument to Archimedes' *Ephodos*. Archimedes' work *aims* to apply new techniques or a high-order version of older techniques to expand the size of the geometric corpus; in the *Ephodos* itself Archimedes proudly records his ability to determine new results, namely three-dimensional planar objects commensurable with objects bound by cylinders and cones. These are not the types of proofs born of late-antique formalist motivations which divide up already-existing solutions.

A different solution is hinted at in the work of Netz (2009a), who reads the *Ephodos* with the narrative expectations of Greek mathematicians.[20] Seen from this perspective, the *Ephodos* has an interest in generalized mathematical enunciations but lacks mechanically accurate schematics, features which tell against the expectations of engineers but for the expectations of mathematicians. (In 1.2.3 I will suggest that engineers and mathematicians are separate social groups and that they work in largely separate scientific domains.) Although Archimedes' intentions are impossible to know, the reading I argue for in chapter 3 suggests that Archimedes is not reaching out to engineers but rather expanding the space of investigation for mathematicians.

From both Knorr's point of view and my argument it is clear that the central issue in Archimedes' *Ephodos* is the notion of proof. The development of the idea of proof in

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[19] Knorr (1986: 40). The late-ancient commentator Pappus in his *Collectio* (c. 300-350 CE) will often reject a Hellenistic solution on the grounds that it violates some standard of geometrical argumentation and will present a new solution employing 'proper' argumentative techniques.
[20] Netz (2009a: 75-79, 129-57).

Greek mathematics is somewhat controversial but Lloyd (1990) draws attention to the political environment in which early Greek mathematics developed, the argumentative fifth-century city-state democracies.[21] Lloyd suggests that the shared vocabulary of demonstration – such as ἀπόδειξις and ἐπίδειξις from the root δεικνυμί "show" – in the 5th century BCE, shared by oratory, philosophy, medicine, and mathematics, evidences an ongoing concern for the precision of argumentation, whether in the forms of *ad hominem*, *elenchus*, or *reductio ad absurdum*. In the case of mathematics, Lloyd points out that in Simplicius' report of Hippocrates of Chios' quadrature of the lunes, our earliest extant work of specialized mathematical interest (c.425 BCE), where Hippocrates is concerned to demonstrate that the quadrature of the lunes proceeds from the proposition that segments of circles are in proportion to the squares on their bases (itself founded on the proposition that circles are to each other as the square on their bases), there is a lack of specialized terminology for proof.[22] If there is already the recognition of the manner in which mathematical propositions are dependent on other proposition, there is not yet a clear attempt to enunciate *all* formal *a priori* principles. In general Lloyd aims to argue that circa 400 BCE there is an increasing differentiation in the notion of *formal* and *informal* proof, recognized already in Plato's insistence that the demonstration of mathematics (i.e. formal proof) was vastly different from that offered in the law-court (i.e. informal proof). All the same, it is not until late in the 4th cen. BCE that Aristotle first enunciated the syllogistic rules of deductive logic. Thus for Lloyd, following Knorr's famous rejection of the notion of a *Grundlagenkrisis* in 5th century mathematics,[23] the progress toward the *explicit* notion of *formal* proof was a long

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[21] See especially Lloyd (1990: 73-97). Lloyd (1987: 74-78) is less developed, but instead of concentrating on the political context is embedded inside a discussion of the role of literacy in the development of Greek science. Netz (1999b) argues strongly for the fundamental role of literacy in the development of the Greek geometrical corpus.

[22] For more on Hippocrates of Chios see Netz (2004c), who extends Lloyd's (1990) argument by arguing that Hippocrates' discursive and non-Euclidean treatment of mathematics is part of early development of geometrical terminology.

[23] The so-called *Grundlagenkrisis* was mathematicians' discovery that not all numbers can be represented as the ratio of two integer numbers, i.e. the doctrine of incommensurability. (For example, a square of side unit 1 will have a diagonal of unit square root 2, which cannot be expressed rationally.) This discovery was said to have given rise to related problems about the definitions of magnitudes and the types of ratio

development made with increasing specificity over the 5th and 4th centuries BCE. The aim of Greek mathematics was not to define or reflect from a second-order position on explicit formal proof but rather to use formal proofs on mathematical objects. Thus by circa 300 BCE, the traditional date of the canonical text of Greek geometry, Euclid's *Elements*, mathematics had standardized its procedures and structure of proof, ἀπόδειξις.

Lloyd's (1990) second point concerns the subsequent universalizing of geometric proof after Euclid's *Elements*. He argues that, when Greeks argue *more geometrico*, they do not do so as part of a universal program to understand the natural world in a purely mathematical way but that specific features of their examples are used to produce results to specific to those phenomena.[24] For example, Archimedes' *Floating Bodies* considers how mathematical shapes float based on a number of assumptions about hydrologic forces and the shape of the liquid surface: the text offers no argument that these assumptions correspond to the physical world but provides only the mathematical conclusions that follow the assumptions.

> We can say that the development, in Greece, of the demand for *certainty* sprang in part from dissatisfaction shared by a variety of individuals with the merely persuasive. But it is also clear that the way in which the concept of proof was *actually* deployed corresponds to those individuals' responses to *specific* scientific problems as they arose in connection with the various philosophical and scientific issues they investigated. But the important facts *we* need to study – and that constitute *our* problem in attempting to understand these developments – are, in the latter case, the *specificities* of those responses, and in the former, the polemic in which, as a means of outbidding the competition, the claim to certainty was preeminent: it could be denied, but it could not be surpassed.[25]

The sober argument of specific issues serves Lloyd very well when he considers the features of idealization in various mathematizing authors from different periods in

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manipulation possible and hence problems about certain sorts of proof; it was supposedly solved by Theatetus and Eudoxus' discoveries, preserved in Euclid *Elements* 10. But this so-called crisis is an invention of early 20th century scholarship. In addition to the literature criticizing the scholarly invention of the *Grundlagenkrisis* cited by Lloyd (1990: 84), see also Knorr's historicizing of the 1930s literature on the Greek *Grundlagenkrisis* within the modern meta-mathematical debate about mathematical foundationalism in the posthumously published Knorr (2004).

[24] Lloyd (1990: 90-95), a very good argument about the distance between scientific authors, who solve specific problems, and the (often late ancient) philosophers who expound a program of universal mathematization.

[25] Lloyd (1990: 95). All emphasis is in the original.

antiquity. Aristotle, Ptolemy, and Iamblichus are shown to share certain interests in exact argumentation and proof without committing them to the same philosophical aims.

Given the standardization of mathematical proof by 300 BCE and the subsequent development of mathematization, it is all the more surprising that Lloyd finds Archimedes, c. 287-212 BCE, vitiating his arguments. For Lloyd Archimedes figures both as someone whose work shows that "the insistence on rigorous demonstration could and did have certain inhibiting effects"[26] (in reference to Archimedes' *Ephodos* and *Quadrature of the Parabola*) and as someone whose idealizations in his mathematizing of physics in *On Floating Bodies* and *On Equilibria of Planes* indicated "the investigation will cease to be a contribution to *physics* and will become (just) geometry."[27] Thus according to Lloyd, Archimedes' work is too precise for physics but not precise enough for mathematics. I suggest that Lloyd has been misled about Archimedes' work, which, as I argue in chapter 3.3, often concerns the idea of proof in mathematics. If my arguments above are correct, Archimedes' intentions in his mechanized mathematics are meant to expand the domain of the mathematician both in a methodological way – as in *Ephodos* – and in considerations of specific problems – as in *On Floating Bodies*. Lloyd recognizes that one cannot speak generally of *a Greek view* of mathematization of nature but his concern about the phenomena of mathematization as a whole leaves him open to the usual criticisms against cultural arguments drawn from multiple historical periods; and Archimedes simply does not fit the pattern Lloyd proposes. An individual outlier does not invalidate Lloyd's larger point, but it is important to underline that Lloyd's argument about the development and employment of geometric proof does not seem to fit the aims of Archimedes' mechanized mathematics.

In the domain of medicine the sects of the Rationalists (founded c. 300 BCE) and Empiricists (founded c. 250 BCE) are the main medical methodologies of the early Hellenistic period. Empiricism is often portrayed as a purely negative reaction to Rationalism. But as I argue in 4.2, the Empiricists have a positive doctrine of sign-

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[26] Lloyd (1990: 89).
[27] Lloyd (1990: 90).

association and of the primacy of vision. They do reject Rationalist accounts of causality and Rationalists, such as Hegetor and Ps.-Dioscorides, criticize and deride the Empiricists for this rejection. But Rationalists do not doubt that the Empiricists are worthy of the name 'doctor'. Galen, in fact, in a famous passage indicates that Rationalists and Empiricists reach the same therapy from different methodologies.

> τοιαῦτα μυρία πρὸς ἀλλήλους ἀμφισβητοῦσιν ἐμπειρικοί τε καὶ δογματικοὶ τὴν αὐτὴν θεραπείαν ἐπὶ τῶν αὐτῶν παθῶν ποιούμενοι, ὅσοι γε νόμῳ καθ' ἑκατέραν τὴν αἵρεσιν ἤσκηνται.
>
> The Empiricists and Rationalists dispute numerous things of this type with each other, although they apply the same therapy in the case of the same afflictions, at least those who have been trained rightly in each sect.[28]

At least for Galen, disagreements over methodology end where therapy begins. Mudry (1982) too argues that in most diseases the treatments employed by each sect would be the same; only in the case of new diseases would they differ.[29] But the claim that the sects held therapy in common is an over-simplification: first, Galen's proviso indicates many doctors worked outside of the guidelines of their sect and, as we see in chapter 4.3.4, Hegetor the Rationalist and Apollonius the Empiricist disagree about even the possibility of treatment of the dislocated hip. As to why the Empiricists rejected Rationalist attempts to explain causality, I argue in 4.2.3 that the Empiricists thought that the Rationalists had strayed from the traditional role and practices of the physician. To the Empiricists, advances in theoretical medical knowledge were not as important as and could impede the effective care and treatment of patients.

We encounter the same problems in medicine with our sources as in mathematics when we treat scientific thought from the whole of antiquity rather than individual periods. Rationalism in particular was the construction of the Empiricists to name their opponents; but Rationalists themselves went under a variety of names: Herophilean, Erasistratean, Pneumatist. Frede (1987) has emphasized the variety of positions and

[28] Galen *de sectis ad eos qui introdunctur* 1.79K = 12.5-8 Helmreich.
[29] Mudry (1982: 97).

voices in both Empiricism and Rationalism.[30] We have much to gain from restricting our examination of evidence within medicine to specific issues at certain times.

The basic problem we have been considering is the rejection of innovative methods in science. On the one hand, Archimedes' works explores the nature and conditions of mathematical proof. That *some sort* of proof is necessary for formal mathematics is not in doubt, although Archimedes seems to believe that only formal Euclidean proof sufficed. On the other hand, the debate between Empiricists and Rationalists demonstrates that, at least in Hellenistic medicine, an understanding of causality is still not *the* prerequisite of medicine. The differences between methodological issues in Hellenistic medicine and Hellenistic mathematics show that there are strong specific considerations at play in the methodology of Hellenistic science. One cannot say that there are formal demonstrative prerequisites for 'science' as a whole. To what extent each science determines its own methodological requirements remains an important question.

Yet there are reasons to suppose that there are strong similarities across sciences between our test cases in chapters 3 and 4; and here we must consider science as a cultural phenomenon in the Hellenistic period. First, the methodological disputes of Hellenistic science are disputes within science, set apart from broader cultural concerns. Archimedes is concerned with how mathematical proof occurs and whether a plane figure can be reanalyzed into a set of its constituent parallel lines. The Empiricists and Rationalists are debating about causality, anatomy, and the role of the physician in medicine. These are issues germane to individual sciences, the first-order questions of the science: what counts as knowledge within a science and the structure by which results are achieved. The Hellenistic debates we have been considering are much more isolated in culture than the debates of, say, the Hippocratic *On the Sacred Disease*, which engages other scientists, philosophers, and magicians.[31]

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[30] Frede (1987: 96-7). Empiricism, unlike Rationalism, was a self-identified sect. Von Staden (1982, 1997a) has even cautioned against attributing a cohesive, collective identity to individual sects within Rationalism.

[31] For the cultural position of *Sacr*. *Morb*. see Lloyd (1979: 37-48).

Second, the rejection of the innovative methodology is accomplished on one level by a rhetorical call to the traditional *aim* of the science. Archimedes accomplishes a sort of result but it must be completed with a formal Euclidean-style argument. What counts in mathematics is the formal proof of a result: the result itself is not enough. The call of traditionalism is even more clearly seen in the debate between Empiricists and Rationalists. The Empiricist critique of Rationalist principles uses the features of fifth-century intellectualism to call for a style of medicine in which the doctor is a caregiver, not a researcher. Medicine aims to care for patients, the Empiricists say, and superfluous knowledge of causality and anatomy has no place in healing medicine.

1.2.2 Critique of Lloyd

The rejection of innovative methodology is not simply a rhetorical trope: the claim of tradition within a science is an assertion of a particular kind of intellectual investigation by a particular community. Lloyd (1990) argues that these phenomena hold true according to the community of scientists themselves, a social *explanans*. I agree with the most basic version of this thesis; but I have already suggested that Lloyd's argument is open to the criticism that all arguments collapsing multiple historical periods into one culture suffer, since Lloyd develops historical theories about all Greek science from the Classical period evidence. Again, I wish to pursue this criticism with the aim to improve and better specify Lloyd's conclusions in the case of Hellenistic science 300-150 BCE.

In Lloyd's view, in contrast to the intellectual culture of ancient China roughly contemporaneous with ancient Greece, Greek intellectual culture is very occupied with foundational issues, i.e. *justification*.[32] Moreover, Greek intellectual culture is more occupied at the level of theory than Chinese intellectual culture. Lloyd connects both of these – the drive for theory and the drive for theoretical justification – with the agonistic political environment of ancient Greece.[33] The divergent political and resulting social

[32] See Lloyd's (1990) concluding remarks, especially (1990: 118-122, 124, 133-134, 142-144).

[33] This has been a theme in nearly all of Lloyd's work, especially in light of comparative material from other ancient civilizations: see Lloyd (1979: 246-264), Lloyd (1987: 78-108), Lloyd (1990: 130-144). But also compare Lloyd's (1987: 78-83) important qualification that "not the *whole* of Greek science and

contexts in which ancient Greek and Chinese scientists worked is placed even more to the center as the *explanans* in Lloyd's more recent comparative work on ancient science in Greece and China, Lloyd (1996), Lloyd (2002), and Lloyd and Sivin (2002). Historians of ancient Chinese science have been hesitant to accept Lloyd's conclusions for areas outside of deductive mathematics.[34] I will consider only Lloyd's treatment of Greek science. Naturally comparative work on ancient Chinese and ancient Greek science has the effect of flattening the changes within a culture over time and in Lloyd's comparative treatment Hippocratic works, Archimedes, and Ptolemy are all broadly part of the same Greek culture.

Lloyd's thesis is this: in the Classical period Lloyd argues that the democratic ideology of openness[35] builds an agonistic environment in which scientists, following the

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philosophy … can be so characterized [to depend on the openness of public debate]" and its accompanying footnote Lloyd (1987: 78.n106) with reference only to classical period works.

[34] See Hart's (1999) larger critique of twentieth century scholarship's project comparing China and the West. Hart praises Lloyd's (1996) attention to the particulars of the sciences but finds, after Lloyd's caveats, little difference between ancient Greece and China apart from deductive geometry. He points out that it is difficult to say just what sort of justification is appropriate in another sciences, especially in the life sciences. It is some support to Hart's criticisms that even the *locus classicus* for the deductive achievement of Greek science, Euclid's *Elements*, ignores certain foundational issues: the opening geometric books presuppose certain notions of continuity, of space, etc. and the arithmetic books, a closed system to themselves, presuppose basic notions of measurement, counting, etc, all without articulating them. On Euclid's implicit assumptions see Mueller (1981: 14-16, 58-63), especially (1981: 63): "If one makes allowance for the difference between numbers and geometric objects and hence for the somewhat different sense attaching to such notions as addition and equality, [Euclid's] arithmetic assumptions are basically generalizations of his geometric ones."

[35] Lloyd (1990: 8): "The thesis of my first two studies develops a well-known argument [in a footnote Lloyd refers to the work of J.-P. Vernant, *The Origins of Greek Thought* and *Myth and Thought among the Greeks*; Lloyd refers to his own (1979) and (1987) works as further explications of Vernant's thesis applied to Greek science], that the key factors at work are to be found in the political circumstances of ancient Greece in the classical period, most notably in the nature and intensity of involvement in political life in the autonomous city-states of that period. In the law-courts and assemblies many Greek citizens gained extensive first-hand experience in the actual practice of argument and persuasion, in the evaluation of evidence, and in the application of the notions of justification and accountability. This experience is all the more relevant to their expectations in other contexts because so much philosophical and scientific discussion too was cast, precisely, in the form of similar debates between opposing points of view. Moreover even when the Greek political practice can be seen to diverge from the image it presented of itself – its ideology – that does not make the image any the less significant as an indication of what was believed or at least held up as an ideal – a point that has special relevance, as we shall see, in connection with the ideology of democracy in particular." Lloyd is arguing that the social context of debate in the 5th and 4th centuries becomes the social context of later Greek intellectual activity. Particularly, Lloyd is arguing that the ideology of democracy, the "propaganda of openness" (Lloyd (1990: 63)), which makes debate and judgment available for all, leads to a social context of accountability, evidence, and proof.

practice of sophists,[36] wage polemic against their rivals; the polemic in turn creates a scientific drive for secure demonstration and an emphasis on justification. In the Classical period Lloyd's thesis explains both the evolution of scientific debate and the movement in research toward sure methodological footing. In the Hellenistic period Lloyd argues that polemic remained the social environment of science, fostering the scientific drive for secure demonstration and justification. Within the Hellenistic period, Lloyd's thesis explains the Classical period genesis of agonistic scientific debate and thus the continued movement toward justification. In Lloyd's view there are few differences in the agonistic environment of science in the Classical and Hellenistic periods; the agonistic environment, first developed out of the democratic ideology of the Classical period, continues to drive the direction of scientific research in the Hellenistic period.

Lloyd's argument leads to a focus on aspects of second-order notions associated with science, namely explanation, investigation, argument. But a focus on second-order material about the nature of science can obfuscate the proliferation of first-order theories of the Hellenistic and Imperial periods' investigation into nature. As Lloyd has shown, science and scientists in the Classical period are constantly engaged in polemic against other scientists and philosophers and magicians and, to a lesser extent, traditional mythologies. Science as an intellectual phenomenon is part of the broad panorama of

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[36] In a long and important discussion Lloyd (1987: 83-102) considers the many persons of the classical period who illustrated *sophia* by public declamation or generally in front of audiences: these social occasions magnify the role that is given to innovation, to authorial egotism, and to criticism of the speaker's intellectual opponents. Although most of Lloyd's evidence concerns philosophy and the sophists, there is evidence for its relation to science too. In particular the medical writers tried to distinguish themselves from other sophists, even as their work shows affinities with sophistic *epideixeis*. Lloyd's point is that debate in science itself came to be emphasized under the influence of the agonistic display of 5th century intellectuals of sophists, rhetoricians, and philosophers. Lloyd (1987: 101-02) concludes his argument: "Yet overt innovativeness in speculative thought and corresponding self-distancing from tradition stem not only from the spread of literacy (itself no guarantee that such attitudes will be adopted), but also from a complex, pluralistic social and cultural situation. What may be particularly important there is the development of new modes of rivalry and competition, calling for new styles of self-justification. In philosophy too, as in medicine, the individual often thought of himself as participating in – and sometimes literally participated in – a debate in which the personal contribution of each participant was clearly marked as *his*, even when he did not go out of his way (as so many did) to stress his originality explicitly. When we speak of Greek writers needing to win and hold an audience, *audience* is often the apposite term, and it may be to that interaction with audiences, and to the development of contexts for that interaction, that we have to look for the chief clues to the understanding of the particular positive and negative modalities of innovativeness in ancient Greece." Emphasis in the original.

critical investigations of the world in the 5th and 4th centuries BCE: philosophers and scientists are sometimes, perhaps even often, the same people.[37] The *physikos* who is both philosopher and scientist easily moves between investigating types of explanations and the explanations themselves. Yet, in the later periods, few philosophers after Plato and Aristotle – i.e. few Hellenistic philosophers – concerned themselves with the first-order questions of science.[38] Further, very few scientists concern themselves with second-order questions about their investigations.[39] But Lloyd (1987) claims that certain features about the accumulation of data constrict later scientific thought.[40] For example, since Lloyd considers the Greek achievement in axiomatic mathematics the *locus classicus* of the desire for certainty in face of the agonistic debate, those works of applied mathematics which post-date Euclid's *Elements* Lloyd therefore contends are best seen as attempts to achieve the desired certainty and avoid debate. Lloyd sees a lack of second-order questions in the discussion of Archimedes referenced in 1.2.1. But Lloyd's claim that later Greek science is more constricted and thus less concerned with second-order questions privileges the observers' investigation of second-order questions in science. It is better for a historical study to follow the actors' interests: the sheer proliferation of names of scientists in the Hellenistic and Imperial periods is indicative of interest in first-

[37] The exception – Socrates – proves the rule that nearly all philosophers had scientific interests and many 'pure' scientists (e.g. Archytas, Eudoxus) had philosophical interests.

[38] The rising philosophical tides of Epicureanism and Skepticism were notably hostile to scientific investigation, attacking respectively the second-order claims about the value inherent in nature and causality; see the papers collected in Barnes (1982). Nonetheless there are important exceptions. Older schools of philosophy still had sway; see von Staden (1997b) on Peripatetic influence in the early life sciences at Alexandria. A few Epicureans and Stoics pursued science: among the Epicureans Philonides of Laodicea-on-the-sea was a geometer; among the Stoics Posidonius of Apamea was notable for his interests in physical geography and mathematics, for which see White (2007). Nussbaum (1994) shows the importance of the cultural figure of the doctor to Hellenistic philosophy but does not engage specifically with medical authors.

[39] Galen almost proves the rule by being a notable exception. The silence of the Hellenistic mathematicians about their metaphysical views on the ontological status of mathematical objects is notorious.

[40] Lloyd (1987: 104-05) explores Thomas Kuhn's essential tension between tradition and innovation in science and maintains in general that there is a certain degree of dogmatism to post-classical science, including the Hellenistic period. He argues (1987: 288-99) that three phenomena – regression of the *explanandum*, suspension of data, and denial of data – illustrate the constricting effect of the accumulation of ideas in science.

order questions of science.[41] Hellenistic and later scientists are concerned with specific issues and problems within their science, not the features of explanation as a whole: Hellenistic scientific debate has shifted primarily to first-order questions.

Lloyd's thesis further assumes the desire for certainty does not change between the Classical and Hellenistic periods. Yet if we attempt to apply Lloyd's thesis to the case studies of chapters 3 and 4, problems develop on this very issue of historical continuity. As I have said, Lloyd's argument about agonistic debate leads him to expect justification in Greek science, a sort of negotiation of the cultural anxiety about the validity of scientific reasoning in the face of social criticism. But as I argue in the case studies, neither Archimedes nor the Empiricists are concerned purely with justification for its own sake. In fact, both adopt methodological strategies which increase the uncertainty of the scientific result. The Empiricist critique of the Rationalists' causal chain is an application of skeptical arguments about the indicative sign; in its place the Empiricists employ the commemorative sign which is more associative than demonstrative. Archimedes' mechanical method depends on a series of undemonstrated arguments about the composition of infinite sets and their summation.

Lloyd's thesis about the development of scientific debate in ancient Greece shows that the direction of research remains broadly constant and thus leads us to expect a continued progression and development toward apodeictic demonstration and rational justification in the Hellenistic period. But the methodology of both Archimedes and the Empiricists vitiates this thesis. For Lloyd, therefore, these problematic elements must be read within the context of his thesis. Lloyd reads Archimedes and the Empiricists as negotiating the anxiety of scientific culture about the increasing strictness of methodological formalism: that is, as the move toward justification intensifies, so too must methodological dogmatism within science.[42] For Lloyd, Archimedes and the Empiricists reject the trend toward formalism for their own reasons. Insofar as Archimedes and the Empiricists avoid the methodological emphasis on justification,

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[41] See Keyser and Irby-Massie's (2008: 4, 937-89) remarks on statistically significant stability in the number of scientists (judged by name alone) from 300 BCE-150 CE and the sudden decline afterwards.
[42] Lloyd (1987: 158-67) on the Empiricists (in a chapter titled "Dogmatism and Uncertainty"); Lloyd (1990: 89-90) on Archimedes, cited above.

Lloyd's argument may be correct. But my reading of these texts is a deeper challenge to his view: Lloyd's argument cannot explain why Archimedes' and the Empiricists' rejection of methodological formalism takes the form it does.

I argue that it *is* meaningful, when science is considered as a cultural phenomenon, that both Archimedes and the Empiricists ultimately reject new methodologies in a certain way. If my reading is correct, Archimedes and the Empiricists embrace their particular methodologies and reject others in the name of the *aim* of their science. If I am correct in arguing that both Archimedes and the Empiricists polemicize against their opponents about the aim of their science rather than certainty or justification, then there is a common direction to certain intellectual currents in the Hellenistic period across mathematics and medicine worthy of consideration as a cultural phenomenon. My claim that the aim and methodology of a science are distinct entities within Hellenistic science is a direct challenge to Lloyd's thesis, in which the formalist methodology and the aim of the scientific practitioner are an intertwined consequence of success in agonistic debate: in Lloyd's thesis the aim of science is the increasing movement toward research grounded in axiomatic justification. Lloyd's thesis cannot encompass a reading of Hellenistic scientific methodology which promotes some other aim at the expense of a formalist justificatory methodology.

In sum, the critique I have offered of Lloyd is based on a disjunction between the Classical and Hellenistic periods: I see difference where Lloyd sees continuity in his presentation across historical periods. I do not want to reject Lloyd's insight that the agonistic polemic of Classical Greek science starts a trend toward apodeictic demonstration. Rather, as we have seen, this argument is not sufficient to explain other features of Hellenistic science. All the same, I wish to be more suggestive than dogmatic: the material we will be considering seems at odds with Lloyd's thesis, but I do not want to claim that *all* Greek scientific material of the Hellenistic period is so.[43] Readers will note that I have concentrated exclusively on a narrow sense of scientist – formal mathematics and trained physicians – to the exclusion of scientific technicians –

[43] I show in chapter 2.1.1 that Herophilus' pulse theory aims for greater certainty by its methodological investigation of *physis*.

root-cutters, midwives, builders. I do not wish to place one group inside science and the other outside in the old way; Lloyd has done much to restore rightfully the members of this latter group to an integral place within the continuum of the ancient scientific community.[44] All the same, I think it is clear that the authors we have been considering associate intellectually with other scientific actors in a narrow sense of scientist – if not exclusively actors of their own science – and I believe it is worthwhile to follow the actors' interests.

Therefore, let us say that there is a *group* of Hellenistic scientific authors whose scientific traditionalism does not stem from the pursuit of certainty of foundational issues. As I argue in chapter 4, the Empiricists are as equally concerned with the physician's cultural role of healer as with methodological epistemology. And as I argue in chapter 3, Archimedes' *Ephodos* intends to expand the domain of geometricians while reinforcing the priority of Euclidean deductive structures. What these two case studies seem to have in common is an interest in results: Archimedes with results within geometry and the Empiricists with results within healing medicine. To (re)state a general principle – made most famous by Thomas Kuhn – results in science are not necessarily in conflict with scientific traditionalism.

1.2.3 A Social *Explanans*

Now the historical problem we confront comes more sharply into focus. For several consequences follow once the distinction between aim and methodology in science is in place. First, we need to separate historical *explanantia* for the aim of the science and for its justificatory methodology. Lloyd has identified the *explanans* for the formalist methodology; we must identify the *explanans* for the cultural aim of a Hellenistic science. The type of *explanans* we are looking for must explain not only the rhetoric but the shape of the research of Hellenistic scientists.

Consider first that Lloyd's thesis is broadly social: the *explanans* for the ethos of scientific debate and polemic is the democratic ideology of Classical Greek society. If we remove the democratic ideological element from Lloyd's *explanans*, two possibilities

[44] Lloyd (1983) is a good example.

seem to remain: first, that the *explanans* of the debate of Hellenistic science is in fact political, but not necessarily democratic; or two, that the *explanans* of the debate of Hellenistic science is not political, but still social. We must remember that we are looking for an *explanans* that is explanatory of the research positions of Hellenistic scientists.

I am skeptical that there is a successful reading showing that the *explanans* of the aim of Hellenistic scientists is operative on a political plane. Certainly there is much evidence of political patronage of science during the Hellenistic period: monarchs supported Herophilus and Erasistratus materially in their research; Archimedes too may have had direct support from his patron. Hellenistic monarchs gave materials, financial support, and cultural opportunities for research.[45] At least *a priori* a political *explanans* would seem to allow a cultural space for investigations of a certain kind without

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[45] Scholarship on science and patronage in Greco-Roman antiquity has focused on the Imperial period and centers around the figures of Galen in medicine (see Mattern (1999), Nutton (1979, 2004: 216-29), Hero in technology (see Cuomo (2002, 2007), Tybjerg (2005)), and Ptolemy in astrology (see Barton (1994a, 1994b)). The issue of patronage in the Imperial period is of course tied to the Roman cultural practice of patronage in general, not only around the figure of the emperor. In contrast to the Imperial period, patronage in the Hellenistic period seems to have centered on the Hellenistic courts; see Herman (1997).

The question of patronage in Hellenistic science has interested only a few scholars who, strikingly, are general historians rather than historians of science. Fraser (1972: 1.305-479) compiles an enormous amount of material relating to Ptolemaic Alexandria but tries to situate all types of knowledge production – medicine, mathematics, engineering, literature, philology – within the institutional context of the Museion. Green (1993: 453-96) locates scientific investigation thoroughly in the attitude of ivory-tower intellectual *theoria*, contrasted with banausic trades; in his view science proper was limited, not motivated, by Hellenistic monarchic authoritarianism. Against Fraser, Geus (2002: 26-30) argues that Eratosthenes of Cyrene, polymath in science and literature, was called to Alexandria as librarian in recognition of his poetry, implying that the Ptolemies did not seek to institutionalize science in the Museum. In medicine in particular von Staden (1989: 1-31, 35-50) argues that Herophilus was never a member of the Museion and cautions (1996: 106.n76) that patronage may take many forms, not only institutional support.

Future consideration of Hellenistic science within a court environment might start from the impetus of Biagioli's (1993) *Galileo, Courtier*: this path-breaking work argues for a thick social description of a court environment that considers in tandem political courtiers, poets, and scientists. Biagioli argues that the cultural practices of politics, art, and science at court can be understood within an anthropology of gift exchange; scientific knowledge thereby becomes a cultural product honoring the patron in exchange for higher social status and financial support for the scientist. Intellectual polemic between scientists is thus read in the context of social jousts and exchanges between scientists' patrons. Since Netz (2009a) has shown that Hellenistic mathematics participates in the literary aesthetics of Hellenistic court poetry, it is therefore conceivable that Hellenistic science (not just scientists) participates in the social life at the courts of Hellenistic monarchs. Important among the numerous studies of the place of Hellenistic poetry at court are Wilamowitz (1924), Griffiths (1979), Cameron (1995), and Stephens (2003).

predetermining the outcome of those investigations. And I would not want to discourage an investigation along these lines: there is much serious historical scholarship to be done here.[46] Wickkiser (2008), a recent classics monograph, argues that the sudden spread of the healing medicine of Asclepius in the late 5th BCE century is directly correlated with Athenian imperial policy during the Peloponnesian War;[47] and Shapin and Schaffer (1985), one of the most famous case studies in the discipline of the history of science, is dedicated to the idea that the same social forces motivate both the politics and science of a period. But can political patronage explain the scientific positions that scientists take? For science of the Hellenistic period I consider a social *explanans* more promising and will pursue it for the rest of this dissertation.

Therefore I maintain that the *explanans* of the debate between Hellenistic scientists is operative on a fundamentally social level. The social group I appeal to will be, variously, those interested in science or scientific practitioners. (I mean that the first group – those interested in science and natural phenomena – will include scientific technicians, e.g. nurses, engineers, philosophers, and will be a larger group than the second, more narrowly defined as practicing scientists.) I noted above that the material I am considering was more isolated in Hellenistic culture: the audience tended more

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[46] Another important contextualization largely unexplored in scholarship on Hellenistic science is the relationship of science to its political context (beyond the motivation of patronage; see footnote 45), namely the possible discourses of imperialism and colonialism. Scholars are of course divided on attempts to model scholarship on Hellenistic literature and history on studies of modern European colonialism; here most work in the discipline of Classics has focused on Ptolemaic Egypt. For important scholarship on imperialism and colonialization dealing with textual sources in Hellenistic literature and history see Stephens (2003) and Manning (2010) for positive assessments and Bagnall (1997) for a negative assessment. For scholarship in the history of science see Flemming (2003) for a positive assessment reading Hellenistic medicine in the context of imperialist projects of knowledge; see von Staden (1989: 1-31) for a negative assessment of Egyptian influences on Greek medicine in Ptolemaic Alexandria, a claim further supported by Lang's (2004) investigation of medicine in the Egyptian chora (an *interpretatio graeca* for science), the lack of royal institutional support for Alexandrian medicine apart from vivisection, and the consequent implication that Greek medicine was not part of a top-down hegemonic project of knowledge. I thank Professor Jennifer Gates-Foster for providing bibliographic help and discussing these issues with me at length.

[47] See especially Wickkiser (2008: 90-105, 107).

toward practicing scientists than lay people. These are elite texts, written by elites and for an elite audience.[48]

The direction of authorial moves is also indicative of a certain composition of audience. I will not be able to show in the coming readings of the works of Herophilus' pulse theory, Archimedes' *Ephodos*, and the fragments of the Empiricists that doctors and mathematicians attempted to reach out to sciences beyond their own. Herophilus' appropriation of musical theories, Archimedes' use of mechanical ideas, and the Empiricists' appropriation of contemporary skepticism were not overtures meant to bring musicians, mechanics, and philosophers into discourse with doctors and mathematicians. Instead, the appropriated theory was turned inward, back toward the narrow group of practicing doctors and mathematicians. So when we talk of scientific practitioners, we mean narrowly 'doctors conversing with doctors' and 'mathematicians conversing with mathematicians'. Each science becomes its own social network and group. Thus, to speak of the social level at which the *explanans* of the debate in Hellenistic science operates is to speak of the debate within the community of *a* particular science.

We see the idea of a domain developing. For each science – mathematics, medicine, geography – there is a group of scientists studying it. The science is a well-defined cultural practice in a particular area of knowledge production, a domain or field.

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[48] To put it in a more Foucauldian theoretical frame (I mean the postmodern Foucault of *Discipline and Punishment* and *History of Sexuality*), we struggle to find a nexus of power and knowledge in the scientific material of the post-Classical world. Broader culture is little impacted by the categories of scientists. In mathematics, Netz (2002) suggests that need to earn a living prohibited all but the wealthy from attempting to learn mathematics, much less become practicing mathematicians. For the gap between those with minimal numeracy and the theoretical mathematics represented in our extant texts see Asper (2009). In medicine, Flemming has argued in a series of articles (2003, 2007, 2009) that Hellenistic and Imperial period medicine can be read as part of the discourse of empire. These are top-down models, imposing on medical texts a structure either of colonializing successor kingdoms (2003) or of the Rome/periphery dichotomy of the Imperial period (2007, 2009). To my mind, Flemming's articles are unconvincing attempts to find a nexus of power and knowledge in scientific texts of the Hellenistic period; at best they are a contextualization of cultural categories on science, not of scientific categories on culture that Foucault's thesis requires. (It ought to be remembered that Foucault was particularly dependent on 'technologies' as an expression of power. In a series of articles Forman (2007, 2010) has forcefully maintained that the primacy of technology over theoretical science is a postmodern ideology.) The failure underscores my larger point that broader culture in the Hellenistic period was for the most part disinterested in science. (I would not endorse the view of Green (1993: 453-96) that scientists were equally disinterested in society.) Future scholarship to find a bottom-up approach to the nexus of power and knowledge might

As the definition of a domain becomes increasingly well-defined, with its own methodology and problems, it creates specialization and isolation for its cultural practitioners. There is a cultural symmetry to the natural elements studied and those studying them. Thus, to speak of Herophilus, Archimedes, and the Empiricists as engaging in "isolated debates" is to describe simultaneously the scientific question and scientific community as culturally "isolated".[49]

To speak of domains and scientific communities is perhaps to speak analogously to Thomas Kuhn's notion of paradigms. Famously, Kuhn (1996, first ed. 1962) argued that there are two stages in the development of science: normal science and revolutionary science. This study's interest is Kuhn's normal science. According to Kuhn, during normal science scientists operate with a paradigm example of how to conduct a study within their field.[50] Doing science is to follow the example of a solved problem, the paradigmatic case. Kuhn uses paradigm in two senses: (1) the example of puzzle-solving that scientists operate with in their daily investigations, and (2) the metaphysical commitment that accompanies the puzzle-solving exemplar.[51] Now Netz (1999b) has criticized the discussion that followed Kuhn's (2) sense of paradigm:

> [T]his is a misguided debate: it starts from the least useful sense of 'paradigm' (as metaphysical assumptions) – least useful because much too propositional. To explain: Kuhn has much of interest to say about normal science, about the way in which a scientific community is united by a set of practices. But what Kuhn failed

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utilize the best scientific texts for a project to find disciplinary technologies, namely mechanical treatises and therapeutic texts, which are a small part of the extant scientific corpus from these periods.

[49] Further prosopography of Greco-Roman scientists would lend credence to my schematization. The prosopographical tables of Greco-Roman scientists in Keyser and Irby-Massie (2008: 991-1020) are a massive collection of data in a single place. There is not as much overlap between disciplines as accounts usually imply. In a smaller data sample of doctors from the third century BCE listed in Appendices C and D only five physicians – Erasistratus of Ceos (Erasistratean, App. C footnote 62), Andreas of Carystus (Herophilean, App. C footnote 66), Neileus (App. D no. 21), Nymphodorus (App. D no. 33), and Perigenes (App. D no. 42) – out of eighty-three have interests in non-traditional domains of medicine (that is, outside of pharmacology), a ratio of 1:16. That the final four apart from Erasistratus flourished around 240-210 BCE and worked on the intersection of medicine and mechanics is suggestive of a strong cultural explanation. For Erasistratus' mechanical interests, see von Staden (1997b); for Andreas' mechanical interests, see von Staden (1998).

[50] See especially Kuhn (1996: 10-91), the account of normal science.

[51] Kuhn (1996: 174-191) and Barnes, Bloor, Henry (1996: 101-105).

> to articulate is that practices are just that – practices. They need not be, in general, statements in which scientists (implicitly or explicitly) believe...[52]

Netz further argues that the debate about metaphysical assumptions obscures the role that practices have in uniting a scientific community and that the goal of a historical study of science should be to illuminate those practices of normal science. For Netz's *The Shaping of Deduction in Greek Mathematics* this takes the form of the shared cognitive process of deduction in Greek mathematics. The present work follows Netz's suggestion that studies in the history of science should aim to articulate the practices uniting 'normal science'. I am therefore concerned with questions about the composition of groups and the common practices that unite those groups.

1.3 LITERARY TOOLS

1.3.1 Systems of Allusivity and Reference

One of the main areas this dissertation will focus on is the appropriation of the sciences of the Hellenistic period. This is problem in a type of intellectual influence – engagement of sources, of theories, of results. Several theoretical models may help in this area: *Quellenforschung*, allusion, intertext. Although these models are mostly from the provenance of literary studies, there is no reason why they should be not applied to questions of intellectual influence. I conceive of particular Hellenistic scientists as creative thinkers in treating problems in their sciences who employ theories or results of a different science for their own ends and purposes; we will therefore be concerned with a dynamics of appropriation of the historical actors, to borrow from Hinds's (1998) title.[53] The theoretical way in which this study will talk of a dynamics of appropriation will be as intertext.

Intertextuality is, broadly speaking, the referential employment of cited authority outside of the immediate context. Kristeva (1980) invented the concept of intertextuality and defined it as an ahistorical phenomenon:

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[52] Netz (1999b: 2).
[53] Hinds (1998), *Allusion and Intertext: Dynamics of Appropriation in Roman Poetry*.

> [A]ny text is constructed as a mosaic of quotations; any text is the absorption and transformation of another. The notion of *intertextuality* replaces that of intersubjectivity, and poetic language is read as at least double.[54]

For Kristeva, these phenomena of the absorption of one text into another may be unrecognizable to an author or a reader: they are a precondition of a text *qua* text.[55] Intertextuality in Kristeva's formulation has no particular literary function; it is simply a condition of a text's existence.

Since Kristeva's original formulation, intertextuality has become one of the most important tools in Classics for determining the relationship of a text to its predecessors.[56] Unlike Kristeva's ahistorical formulation of intertextuality, classicists have extensively debated whether the referencing of another work is an act of the author or of the reader. Since all texts that can be referenced as intertexts must be chronologically prior to some vantage point from which the act of reference originates, the scholarly debate is whether the historical point of view on predecessor texts emanates from the author or reader (where we imagine a continuum of historical readers beginning from the author's contemporaries, to several generations later in antiquity, to Byzantine and Renaissance readers, and so on to twenty-first century readers).[57] In accordance with the anthropological distinction between actors' and observers' categories enunciated in 1.1, this study will treat intertextuality sometimes as the act of the ancient scientific author and sometimes as the act of the reader, conceived of as the modern historian. I will mark the ancient scientific author's ability to allude to predecessor texts as intertextuality$_A$ (actors' category); I will mark the ability of the reader figured as the modern historian to collate and compare predecessor texts as intertextuality$_R$ (observers' category). This methodological stance reinscribes authorial intent within anthropological analysis,

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[54] Kristeva (1980: 66).

[55] See Edmund's (2001: 8-14) discussion of Kristeva's work.

[56] For up-to-date guides to bibliography and further references see Levene (2010: 82-84) and Polleichtner (2010).

[57] For studies in Classics concerned with intertextuality as an act of the author see chiefly Thomas (1986); for intertexuality as an act of the reader see Edmunds (2001).

namely the actor's intention as an interpretation of the ethnographic observer; correspondingly, the anthropological informant this study interrogates is the ancient text. Both intertextuality$_A$, the category of authorial intent, and intertextuality$_R$, the category of reader-response, are useful theoretical tools for the study of cross-scientific appropriation. Intertextuality$_A$ and intertextuality$_R$ will occur in chapters 1, 2, 3, and 5.

I discuss intertextuality$_R$ first. Intertextuality$_R$ is the reader's experience of the text's allusive references to other works; the reader constructs these allusive references from her knowledge of other texts with what she perceives to be prompts from the text at hand. Since the reader's experience of the text's perceived allusions may or may not correspond to the author's allusive intent, authorial intent is not the category intertextuality$_R$ specifies. Instead intertextuality$_R$ specifies a unique reader-response to phenomena in the text. The type of reader this study envisions is the modern historian, a reader trained in historical knowledge about the Hellenistic world and the history of science. While some individual historians are more broadly knowledgeable about social history or literary history or other aspects of historical phenomena, enough similarities between unique readers exist to classify the modern historian's experience of reading Hellenistic scientific texts as the act of single typologized reader.

Intertextuality$_R$ is this typologized reader's strategy of arranging the similarities and resonances between different historical texts. The word 'historical' guides the conceptual application of intertextuality$_R$. Consider, for example, several scientific texts from the same ancient author which lack precise chronological order but treat a similar topic. (We will encounter this problem with both Herophilus in chapter 2 and Archimedes in chapter 3.) Surely the ancient author knew that he wrote text A before text B; he cannot therefore have possibly referred to text B in text A. But if the modern historian lacks dated evidence, she will not know whether text A precedes text B or vice versa. She may read text A and perceive an allusive reference to text B; she may therefore think that text B precedes text A chronologically. Yet our well-trained historian knows that to argue for a chronological sequence based on her perceptions alone is an unconvincing argument. She cannot solve the problem of chronological sequence

between texts; therefore she suspends the issue of chronological priority between text A and B. And now, since she knows that both text A and text B precede her (although she claims not to know whether text A precedes text B or vice versa), she can treat both texts as possible intertexts of each other from her historical vantage point as a reader. Historically of course her argument is false; yet by treating text A and B as possible intertexts for each other she gains how the texts allude to each other, that is, she gains how text A and B are similar.[58] Intertextuality$_R$ is therefore a historiographical strategy of perceiving similarities between different scientific texts at the expense of establishing a chronology between them.

I now discuss intertextuality$_A$. Hinds (1998) presents an influential version of intertextuality$_A$ focused on the author's referencing of other texts. According to Hinds intertextuality$_A$ runs the gamut from a conscious referral by the author of the audience to another text or work, to the author's unconscious referencing of familiar literary tropes. In its most narrow form intertextuality$_A$ is a move of authorial intent: we may speak of a

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[58] I am concerned with a typologized reader's experience of past texts to which they profitably apply intertexts impossible for the author. Consider Edmunds' (2001: xiv-xv) analysis of Pearcy's *BMCR* review: "A reading of the *Aeneid* at the end of the twentieth century will inevitably find meanings that Vergil's first readers would not have found. Lee T. Pearcy provides a good approach in a review of Catharine Edward's *Writing Rome: Textual Approaches to the City:* 'At his village on what will become the site of Rome, the Arcadian chief Evander names for Aeneas places that do not yet exist, in a city not yet founded (*Aen*. 8.347-48)

> hinc ad Tarpeiam sedem et Capitolia ducit,
> aurea nunc, olim silvestribus horrida dumis.

Augustan present and imagined Augustan past coincide; furthermore, as James Zetzel suggested in his 1993 Jackson Knight Memorial Lecture, *olim* may look ahead to an imagined Augustan future, when the center of Rome will once again be overgrown with wild vegetation, like the monuments of Janus and Saturn which Evander points out. Rome is eternal, and eternally in ruins. Yet is nearly impossible for us to read the past, present, and future of Rome and its ruins simply through Augustan eyes, even when we encounter them in Augustan literature. A dozen lines later, Evander takes Aeneas onto the Palatine, and they gaze over the pastoral scene: *passimque armenta videbant* / *Romanoque foro et lautis mugire Carinis* (*Aen*. 8.360-61). For anyone who has seen or read early modern depictions of the Campo Vaccino, these lines have a penumbra of transhistorical reference that they could not have had for Vergil or his Augustan readers and hearer. There is nothing we can do to silence this additional resonance. Time has added it to our Vergil, transforming him in the process – and is it possible that a Prianesi print or a remark in Gibbon predisposed Zetzel to call our attention to the multiple valences of *olim*, and predisposes us to accept his suggestion?' Pearcy's testimony to the resonances of reading appears here not in some argument for a reader-response approach to literature but as a commonsense observation, elegantly stated, on the experience of a sophisticated reader." Edmund's analysis of Pearcy's review shows that the reader gains

game, whose rules the author defines, in which the author makes moves, all to direct the reader's attention to an intended meaning by way of comparison. Narrow intertextuality$_A$, traditionally called allusion, is a game of appropriating another's work for one's own meaning. The author directs his reader to another text by a correspondence of diction and situational context between his own work and the other text. In its broader form, the act of reference to another text may not be consciously in the author's mind and yet recognizable to a reader. At some point the act of referral ceases to be an act of the author and becomes an act of an intelligent reader who generates new meaning other than the author's intent.

While Hinds concerned himself almost exclusively with Latin poetry, recent important treatments of prose intertextuality$_A$ come from Latin historiography. Levene (2010) has argued that the intertextual references in historical writing, for instance, are constrained by the considerations of the genre within which historical authors are writing: history presupposes "a representation of real events".[59]

> Events in real life may show striking resemblances to other historical events, and people in real life may deliberately choose to model their behaviour or public image on earlier figures. Both can be true whether or not those resemblances happen to be recognized by the historians describing them. Moreover, even if the historian wishes to draw attention to parallels, that can be done in different ways. It can appear in the form of a direct citation of the parallel without reference to any single source, for example, or the description of one set of events may be reworked in order to highlight features specifically associated with the other set—though again without any single source. In addition, many historians draw much of their data closely from relatively small numbers of source texts, and these may or may not have alluded to the resemblances between different past events and their representations in still earlier writers.[60]

Levene's argument is that historians write self-consciously within a tradition of identifiable sources and patterns which are constrained on the one hand by the *realia* of the events to which they refer and on the other hand by the small number of sources

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something that the author did not intend. And as long as we do not confuse reader-response with authorial intent, there are historiographical uses to which scientific historians can apply reader-response intertexts.

[59] Levene (2010: 85).

[60] Levene (2010: 85).

available to the (later) historian and his readers. Reference to things outside the immediate historical text is particularly limited; that is, the reader does not have to work hard to see the "mosaic of quotations" from which the text is assembled.

Levene's argument is, to some extent, also applicable to Greek prose of Hellenistic period science. Certainly Hellenistic period science is constrained by the *realia* to which words refer. Medical texts refer to anatomical parts such as arteries and the heart and to physiological processes such as dilation and contraction of the arteries (although whether these named physiological processes are isomorphic to contemporary Western biomedical physiological processes is sometimes nebulous). Mathematical texts too refer to objects drawn on the papyrus page, such as *the* triangle ΑΒΓ of Euclid *Elements* 1.1. There is active scholarly debate about the extent to which mathematical objects were mental or physical objects for Greek mathematicians[61] but it is clear at least that Greek mathematical authors expected their audience to refer vocabulary for mathematical objects to the diagrams present on the page.

Furthermore, Hellenistic scientists often write self-consciously within the tradition of their science. Archimedes in the *Ephodos* will explicitly refer to mathematical results proven elsewhere, both by himself in another named work and in an elementary treatise on conics in common circulation; Hellenistic physicians commented on Hippocrates' works and cited other physicians' drug recipes in pharmacopia. These are citations of works within the tradition of *a* particular science, that is, within the expected knowledge and reading of the mathematical or medical audience, respectively. In these instances, authors of a scientific domain write to an audience of the same domain.

On the other hand, Levene's argument does not fit other aspects of Hellenistic scientific prose; in particular, the phenomena of appropriation from one science into another does not commit an individual science to be constrained by its tradition. As we will see in chapter 2.2.1, Herophilus adopts a theory of musical rhythm into his analysis of pulse rhythms. Music is not part of the tradition of medicine; indeed, only those

doctors already of sufficiently high class would have been educated in theoretical μουσική "music" as part of a liberal elite education before training to become physicians. The adaption of one science into another is thus a problem for audience expectation in both literary and cognitive terms. How successful a scientist's appropriation of material outside of his tradition is depends therefore on his audience's recognition of the new material and, correspondingly, his ability to mark the new material and integrate it into the old.

Nonetheless, because of the narrowness of training in individual sciences in antiquity, it is not apparent that a general audience would understand the appropriation as *science*; rather, perhaps, a general audience would receive the appropriation as a display of spectacle, the social performance of science. An ancient audience that understands appropriation as science is a narrow audience, a scientific elite educated in multiple sciences and capable of appreciating direct and perhaps indirect allusions to other scientific traditions. Therefore, as I suggested above in 1.2.3, phenomena of appropriation in science are aimed at a very high level of historical actors, elite scientists in the narrow sense.

1.3.2 Technical Terminology

One aspect of an analysis of appropriation is as a social analysis, as will be shown below in 1.4; the other aspect of the analysis of appropriation is as a literary phenomenon, as has been argued. How might an appropriating scientist mark new scientific material within his own domain? Since theories of intertextuality$_A$ depend on notions of diction and situational context, it is appropriate to consider dictional content and situational context specific to science.

The language of science and its domains is effectively a technical language. The question of technical language in medical Latin is treated well by Langslow (2000), whose results are generalizable to discussions of 'technical language' in other sciences of Greco-Roman antiquity.[62] Langslow notes that technical language is effectively a variety

[61] See the discussion of 'seeing-as' in mathematical imagination in chapter 3.2.3.
[62] His most important remarks are Langslow (2000: 1-28) with reference to further literature.

of a language, a sociolect, whose community of speakers/writers is also a speaker/writer of at least one other sociolect (determined by sex, age, dialect, class, etc.) both of which may be considered subsets of standard language. To speak of technical language is to include deliberately both the grammar and lexicon of the sociolect. The grammar of a technical language is marked by nominalizations, the frequent use of nouns, and the emphatic preference of nouns in conjunction with weak, copulative verbs.[63] Since the grammar of technical languages emphasizes nouns, it is therefore not surprising that the foremost feature of technical languages should be their lexicons.

Discussion of technical language thus becomes a discussion about technical terminology.

> Technical terms – and their collectivity, terminology – are referring expressions which label the objects of a classification within the relevant *techne.* They are not in themselves abnormally precise expressions, but the items that they label are more precisely defined and classified than is usual in everyday language. The language supplies not the classification but merely the nomenclature for the things classified. The elements of this nomenclature are technical terms and their sum is the technical terminology.[64]

Technical terminology is composed of individual lexemes, the terms, and the hierarchical structure to which they belong, the classification. The specificity of technical terminology, *Genauigkeit*, is as much a product of its situational context (the classification, in Langslow's terminology) as it is a property of the term. Langslow argues that the ideal technical language "consist[s] of a set of referring expressions, each occurring once only, each labeling an item or a class of items that has a well-defined place within a classification of the set of objects of study of the technical discipline".[65] On this ideal account polysemy of a single lexeme is avoided. The ideal technical language would be easy to identify and catalogue because each lexeme would be used only once and employed within a systematic class which could lay bare the semantic relationships between terms. Yet as a matter of fact Langslow finds that medical Latin at

[63] Langslow (2000: 23-24).
[64] Langslow (2000: 7).
[65] Langslow (2000: 9).

least is polysemous, with a single word often referring to separate items within a class or to items within different classes.[66]

Due to the polysemy of ancient technical language we are forced to consider other criteria which identify technical terminology. Langslow argues that two criteria for deciding what constitutes technical terms are *Fachbezogenheit*, "the extent to which a word is related to a particular specialist or technical discipline," and *Normung*, "the extent to which a word is normalized or standardized in its usage".[67] With *Fachbezogenheit* we again see the need for the idea of a domain or field: technical terms become *fachbezogen* when there are speakers of that domain and terms related to that domain. With *Normung* we see again the implicit idea of a domain: the frequency of the term's use and its consistency in meaning are the means to effect key concepts of the domain; the less frequently a term is used and the less consistent its meaning, Langslow's 'referring expressions', the further we have moved from the central focus of the domain.

In a study of a scientist's appropriation of theories and terms from one scientific domain to another, it is therefore imperative to consider Langslow's criteria to determine the extent of appropriation from one domain to another. First we must ask: how standardized is the meaning of the term within its original domain, its *Normung*? Second, to what degree is this term related to a particular domain, its *Fachbezogenheit*? When a term, e.g. ῥυθμός, is used by musicians, its meaning depends on a well-defined sense of understanding (*Normung*) among musicians that the term refers to a series of musical beats in sequence (its contextual *Fachbezogenheit*). Thus the specificity and contextualization of a technical term refers both to a specific object and the place of that object within a larger language system, and finally, from a larger language system as a sociolect to the broader community of Greek speakers. The technical term is therefore a marker of the linguistic phenomena of a particular sociolect as well as a marker of the social group of speakers of that sociolect, social phenomena. Effectively, technical terms can serve as guides to social groups.

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[66] Langslow (2000: 11-12).
[67] Langslow (2000: 13).

My argument then is that the most important literary feature that an appropriating scientist considers in the appropriated technical term is Langslow's criterion of *Normung*, the standardized specificity of the term. Suppose, for example, that the technical term of one social group, e.g. ῥυθμός, is used within a different sociolect of the same language. The speaker transfers the specific reference of the term to a different contextual setting, preserving the *Normung* but changing the *Fachbezogenheit*. A medical author using ῥυθμός might apply the specificity of meaning ("beats in sequence") within a different contextual structure to produce a different sense of *Fachbezogenheit*: the doctor Herophilus of Chalcedon uses ῥυθμός in reference to the beats of the artery in sequence, thus defining *pulse rhythm*. Whether this new meaning will survive and become established within its new context depends on the community's reception of the appropriating scientist's theories in which the appropriated term exists. If the community accepts it, the technical term may gain a new *Fachbezogenheit*.

We will find that there is a cluster of terms drawn from one science which the appropriating scientist will apply to his own science. In the case of Herophilus in chapter 2, the vocabulary of musical rhythm and proportionality will be central to Herophilus' new object of arterial pulsation. In the case of Archimedes' *Ephodos* in chapter 3, the vocabulary of balance and weight will be central to Archimedes' mechanical way of seeing.

1.4 Sociology of Science and the Semiotic Turn

History of science studies take inspiration from two different and sometimes competing sets of academic traditions, philosophy of science and sociology of science.[68] G.E.R. Lloyd's work has been extensively informed by philosophy of science disputes. Most famous in philosophy of science are the works of Karl Popper, Thomas Kuhn, Imre Lakatos, Hilary Putnam, and Paul Feyerabend. Except for Kuhn and Feyerabend, these

[68] It seems that philosophy of science is well-developed in English-language scholarship whereas sociology of science is better established in French and German scholarship. Rheinberger (2010) is a helpful summary of the twentieth-century tradition of continental European scholarship in the history and sociology of science. See Daston (2009) for a summary of recently divergent trends between sociology of science and history of science in English language scholarship.

philosophers emphasize the theoretical aspects of science: its methodology, structure, and overarching goals.[69] The works of Kuhn and Feyerabend, on the other hand, emphasize the practice of scientists. While not entirely appropriating the work of Kuhn and Feyerabend, many sociologists of science drew inspiration from them. Timothy Lenoir (1998) for instance has written:

> If there are any "origins" of the recent turn [to semiotics], I would trace them to Paul Feyerabend's seminal work, *Against Method*. Those of us who were moved by Feyerabend read his work as an injunction to move away from theory-dominated accounts of knowledge production in science and toward an account sensitive to actual scientific practice, in which theory was simply one of the many important games in town, with experimenters and crafters of instruments and techniques being crucial but silenced laborers in the production of knowledge. The rehabilitation of skill and craft knowledge (even in the domains of theory and mathematical and computational practice), concerns about tacit knowledge and unarticulable skill, experimenter's regress, interpretative flexibility, and negotiated close of debate all contributed to newer accounts of science as a disunified, heterogeneous congeries of activities.[70]

Sociologists of science embraced Feyerabend's advocacy of the proliferation of perspectives on the practice of science. If sociology of science has a goal, it is to describe the practice of science in all its forms without regard for scientists' own theoretical claims for their practices.

One of the leading practitioners of a semiotics study of science is the sociologist Bruno Latour. His work has been very influential in contemporary science studies scholarship but has been little appropriated by historians of ancient Greco-Roman science.[71] On the one hand, the reason is easy to see. Latour is concerned with modern science and technology, whose hybridized combination he calls 'technoscience'.[72] His

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[69] The famous philosophers listed were physicists or interested in physics and all come from the period in philosophy of science when one philosophized about 'science' as a whole, instead of individual sciences. More recent philosophy of science literature considers individual sciences and has paid more attention to the biological sciences, instead of solely the physical sciences.

[70] Lenoir (1998: 2).

[71] Biagioli (1999) is a helpful selection of important literature in the discipline of science studies.

[72] Latour (1987: 29) claims to have invented the term 'technoscience' but Forman (2007: 75.n22) shows that it was already widespread in continental scholarship. The word 'technoscience' has become a primary ideological marker of a postmodern orientation toward scientific history; see Forman (2010: 169.n20) with further reference to Barnes (2005). That science has always been 'technoscientific' (i.e. that the study of

writings are full of sociological analyses of machines and ethnomethodologies of laboratories. Analyses of computer debuggings, of geographical strata displays, of the instrumentation of biochemical laboratories would *prima facie* seem little applicable to science in the Greco-Roman world. But Latour offers many analyses good to think with for historians of pre-modern science too. He describes sociologically how knowledge emerges and circulates in science, the very problem we wish to address in a study of cross-field scientific activity in the Hellenistic period.

Latour's major work, *Science in Action* (1987), pursued the idea of science as semiotics. In *Science in Action* Latour is a certain type of constructivist about science. He is both a realist and a relativist because he believes that it is his sociological duty to follow scientists in action: scientists themselves are relativists when engaged in a controversy about the construction of a fact; scientists themselves become realists after accepting a fact. The constructed fact Latour calls a black box. "The word black box is used by cyberneticians whenever a piece of machinery or a set of commands is too complex. In its place they draw a little box about which they need to know nothing but its input and output."[73] (Latour writes "black box" as two words but I will hereafter refer to Latour's concept as the single world "blackbox.") When a blackbox is constructed and thus assumed as part of established science, scientists act as realists about the blackboxed fact. When a blackbox is deconstructed in an attempt to rewrite established science, scientists act as relativists and claim that the 'fact' is not established.

The blackbox is in effect a sociological semiotic device, whose working are consistent but irrelevant, which is evaluated solely on its in-going sign and out-going sign. The in-going sign is transformed into an ontologically stable output, the "fact". If we take the in-going signs to be signs of Nature, the object of science, the blackbox becomes the liminal point between scientific relativism and realism. In Latourian

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nature has *always* been intermediated variously by machines and other artificial human technology) is an ideological claim of Latour (1993), who has largely framed the debate of historical investigations into technology. While I do not know of any use of the term 'technoscience' by a historian of science in classical antiquity, recent scholarship in Classics has undermined the traditional ontological distinction between *physis* and *techne* in line with broader trends in history of science and technology studies: see Schiefsky (2007), Cuomo (2007), and Berryman (2009); von Staden (2007) is an exception to this trend.

[73] Latour (1987: 2-3).

dualism the ontology of the Nature has moved from the relativist ingoing sign – Nature is the consequence of the blackboxed fact – to a realist outgoing sign – Nature is the cause of the blackboxed fact.[74] Therefore, Latour argues, we can never take Nature to be the *explanans* for the development of a scientific fact. Science-in-the-making is always epistemologically under-determined.[75] By scientists' own logic, science-in-the-making is a relativist affair.

The blackboxed fact becomes incorporated into a network of associations which is used to tie or associate the blackboxed fact into an older group of blackboxed facts. For example, a blackboxed claim about electrolysis of water – that running an electrical current through water produces oxygen and hydrogen gas – depends on older blackboxed claims about Lavoisier's isolation of oxygen and hydrogen, about Faraday's discussion of electrical current, etc. From the realist side of science, Lavoisier's claims about the gases and Faraday's claim of the nature of electricity are established facts which explain the electrolysis of water. By scientists' logic, science-already-made is a realist business.

As Latour envisions the network of science, the 'facts' and objects upon which new research is founded can be understood in a Nietzschean genealogy.[76] Any established fact was, at one time, not an established fact. Once it has become a fact it is blackboxed into the network, where only input and output are known from the blackbox. Scientists form a linkage between a new idea and an established blackboxed fact. In this way science is a very open and clear assemblage of claims which have an established history. (We should avoid the sense that facts are hierarchically dependent on each other: they are a network, not necessarily an ascending chain.) Each claim individually became a fact at a historical moment. One could write a genealogy of an individual claim or of

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[74] Latour (1987: 98-100).

[75] Latour (1987: 260.n4): "The notion of under-determination is also called the Duhem-Quine principle. It asserts that no one single factor is enough to explain the closure of a controversy or the certainty acquired by scientists. This principle forms the philosophical basis of most social history of sociology of science."

[76] I use the adjective Nietzschean in this paragraph to include works in the methodological spirit of Nietzsche's *Genealogy of Morals*; most famous are the intellectual and cultural archaeologies of Michel Foucault. Latour (1987: 92): "The point is that the new object emerges from a complex set-up of sedimented elements each of which has been a new object at some point in time and space. The genealogy and the archaeology of this sedimented past is always possible in theory but becomes more and more difficult as time goes by and the number of elements mustered increases."

several. One could relatively easily show that the entirety of science is historicized, that it was created by people at certain points in time. Latour does not mean that the Nietzschean genealogical project would not be philosophically valuable. But from his perspective as a sociologist, scientists in fact use historicization as a defense, not an attack on their domain: the historicized claim is blackboxed. 'Cantor showed the one-to-one correspondence of transfinite numbers' is intended as 'Cantor showed this; so you cannot deny it'. To Latour this sort of claim ought to be read as, 'We mathematicians all agree with what Cantor showed and our work depends on his established fact'.[77] Thus when scientists invoke the historicization of their discipline they intend to demonstrate their shared agreement of its correctness for their domain; but to Latour the historicization maps out clearly the dependency of the networked claims and blackboxes. Since the claims of historicization take place only on the realist half of science, a Nietzschean genealogy of scientific claims is only half a description of the process by which claims become facts in blackboxes.

To return to science in action, Latour argues, we must consider science in the process of blackboxing facts. To consider science before a fact is established is to enter into controversy between potentially competing claims. Often a claim is made and lays unchallenged or uncited, a phenomenon that demonstrates how later users can give or withhold meaning for a claim. This phenomenon indicates most broadly that meaning-making in science is a collective process; more specifically Latour believes that later users can refuse to associate previous blackboxed claims with a new one.

A reader may draw a conclusion different from the conclusion that the scientific author intends. The phenomenon of reader mis-reading in science can take several different types of readers: the lay reader, who knows nothing about the science, and a spectrum of persons increasingly familiar with the type of claims made in a scientific paper. Scientific literature constantly pushes away the lay reader, Latour writes.[78] Such

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[77] Latour (1987: 90).

[78] Latour (1987: 44): "I do not say that because the literature *is too technical* it puts people off, but that, on the contrary, we feel it necessary to call technical or scientific a literature that is made to isolate the reader by bringing in many more resources. The 'average man who happens to hit the truth', naively postulated by Galileo, will have no chance to win over the thousands of articles, referees, supports and granting bodies

a reader will not be able to argue against the claims drawn in a paper that references data from expensive machines, the authors' institutional credentials, and many other papers from other credentialed people with expensive machines. (Thus Latour's description of the act of reference in a scientific paper is intertextuality$_A$.) Only a reader sufficiently familiar with the background literature would be able *to drive the interpretation* of the scientific paper in a direction different than intended.

Therefore, Latour asserts, a scientific paper is constantly trying to force a single, dominant interpretation upon the reader, even against her will. A paper will employ not only references to other literature – that mass of background information that keeps out a lay reader – but also a number of charts and graphs. "Belief in the authors' *word* is replaced by the inspection of 'figures'."[79] Far from being superfluous, charts and graphs are the essence of scientific papers. It is impossible to disentangle pictograms and ideograms from the scientific text: the entire product is textual. Thus the entire scientific paper has a clear literary goal; the real question is now how to evaluate the claims of the paper.

Since the process of meaning-making in science in action is collective, Latour argues, in evaluating the paper we should consider the connections drawn by the scientists who argue for their claims. These connections are an assembled network drawn from a variety of sources: facts, machines, data points on a graph, citations in scientific literature. We readers are never presented with Nature directly, but only indirectly at best. We are really presented with a chain of weaker and stronger associations which the scientist has compiled into an assembled network; and the development of a scientific 'fact' is the movement from weaker to stronger rhetoric. From Latour's sociological perspective, unless we readers are scientists ourselves, our only ability to evaluate the claims made in a scientific paper is to evaluate the strength of its assembled associations.

> From the observer's point of view none of these people ever think illogically or logically, but always sociologically; that is they go straight from elements to

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who oppose his claim. The power of rhetoric lies in making the dissenter feel lonely. This is indeed what happens to the 'average man' (or woman) reading the masses of reports on the controversies we so innocently started from."

[79] Latour (1987: 47).

> elements until a controversy starts. When this happens they look for stronger and more resistant allies, and in order to do so, they may end up mobilizing the most heterogeneous and distant elements, thus mapping for themselves, for their opponents, and for observers, what they value most, what they are most dearly attached to. 'Where thy treasure is, there will be thy heart also.' The main difficulty in mapping the system of heterogeneous associations is in *not* making any additional assumption about how *real* they are. This does not mean that they are fictitious but simply that they resist certain trials – and that other trials could break them apart. A metaphor would help at this point to give the observer enough freedom to map the associations without distorting them into 'good' ones and 'bad' ones: sociologics [the mapping of associations] are much like road maps; all paths go to some place, no matter if they are trails, carry the same traffic, do not cost the same price to open and to maintain. To call a claim 'absurd' or knowledge 'accurate' has no more meaning than to a call a smuggler trail 'illogical' and a freeway 'logical.' The only things we want to know about these sociological pathways is where they lead to, how many people go along with what sort of vehicles, and how easy they are to travel; not if they are wrong or right.[80]

To get our bearings in a scientific paper we have to consider the different types of connections drawn from very different sources. Claims from other scientific papers appear different than data from machines, different from human sources, etc. And yet to make this distinction presents a distinct problem: what matters is the move from weaker to stronger associations, not the types of heterogeneous elements which compose the assemblage. Scientific facts and technologies which incorporate scientific facts do not disseminate themselves incorporeally but are always accompanied by people: "the black box moves in space and becomes durable in time only through the actions of many people; if there is no one to take it up, it stops and falls apart however many people may have taken it up for however long."[81] Facts may be intellectually stubborn things but facts as blackboxes without allies force their interpretation on no-one.

The assemblage of the blackbox moves in two directions: who it is designed to enroll and what it is tied to in order to make the enrollment inescapable. The system of alliances knitted together by the blackbox means that it has become the obligatory passage point for people and facts. The obligatory passage point is a sociological notion

[80] Latour (1987: 205).
[81] Latour (1987: 137).

drawn from Callon (1986).[82] The obligatory passage point is a cultural space through which a social group must pass to reach its desired end. In the earlier example of the electrolysis of water, the interests of environmentalists and engineers and investors who want to produce an automobile running purely on the water in fuel cells align: for these groups, desired success passes through water electrolysis blackboxed into a fuel cell. The ability of the fuel cell itself – its efficiency, its manufacture – thus becomes the cultural point through which the aims of these social groups must pass, their obligatory passage point. The example of the fuel cell makes clear both those that the assemblage enrolls – the investors and the environmentalists – and its blackboxing to make their enrollment inescapable. All groups are tied to the statement *the fuel cell electrolyzes water into hydrogen and oxygen*, a statement networked by Lavoisier's and Faraday's work on oxygen, hydrogen, and electricity.

Notice that agency and intention have now entered into Latour's account of science. Moreover these agents and intentions are not only those of the scientists themselves, they are those of the allies enrolled in the assemblage. Technoscience is thus also a system of control, populated by various groups. Various kinds of groups are linked together in the example of the fuel cell: facts, such as Lavoisier's discovery of oxygen; machines, such as the fuel cell itself; and human social groups, such as the potential investors. The fuel cell knits together these semiotic and material elements from different backgrounds because it has become the cultural space through which these elements must pass, their obligatory passage point. As a point of control then, whoever controls the obligatory passage point controls the assemblage. Latour speaks of "spokesmen" in this regard: elements that are represented by other elements Latour calls 'actants'.[83] Actants include other people, materialities, semiotic elements. The spokesman for these actants is always trying to control their behavior and keep the assemblage together.

If the interpretation of a claim is dependent on both author and reader of a scientific paper, how then can the author consistently drive a single interpretation upon a reader? As we saw above, the reader is referred first to other texts produced by other

[82] Callon (1986) is a paper key to establishing Actor-Network Theory, described more below.
[83] Latour (1987: 84).

sciences, which themselves are or contain blackboxed facts; the reader is then referred to figures and diagram in the paper at hand. Figures, diagrams, and data sets are inscriptional products of laboratory machines, which are physical blackboxes enclosing facts.[84] Yet the assemblage of blackboxed facts – both physical and semiotic – does not simply lie open for the reader's unhindered inspection; the paper's author constantly speaks for the assemblage and its elements as the spokesman of these actants. The rhetoric of the paper presents the spokesman as an objective representative of the actants.[85] The spokesman claims to represent accurately the intent of the actants: the intent of the blackboxed inscriptional machines, of the other scientists' papers, of the scientist's own team.

Consider the engineer of a particular fuel cell, who claims that it is two times more efficient than previous cells. His presentation to potential investors refers to the work of researchers of electrical circuitry at academic institutions as well as charts with peaks and valleys of his cell's performance. The engineer has constructed his fuel cell as the obligatory passage point for those researchers' claims about the electrical conductivity of rare metals and his own particular configuration of electrical circuitry. The engineer serves as the spokesman for these actants. Moreover, the fuel cell is networked in to older claims; the fuel cell blackboxes older 'facts', such as the electrolysis of water and Lavoisier's and Faraday's chemical elements. The engineer has enrolled these facts as allies in his network; at the same time he claims to represent them objectively as 'actants'. Callon (1986) calls the spokeman's strategy to knit together the assemblage of the actants by the French term 'interessement': the engineer has made an interessement of social groups and natural elements.[86]

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[84] See Latour and Woolgar (1986: 51, 89.n5) for the analysis that machines and their signifying systems are sociological inscriptions devices: an inscription device "allows one to describe a whole set of occupations in the laboratory, without being disturbed by the wide variety of their material shapes. For example, 'a bio-assay for TRF' [a biochemical compound] counts as *one* inscription device even though it takes five individuals three weeks to operate and occupies several large rooms in the laboratory." The sociological observer notes the common interaction between people for a single purpose and the purpose, inscription, is thereby described without need to reference the materialities of the machines or communication systems: what matters is the semiotic traces produced and their signifying the system from which they come.

[85] Latour (1987: 78).

[86] Callon (1986).

The investors want to put the engineer's claims to the test before they invest their money. They want to know whether the engineer represents his fuel cell accurately, that is, do the actants enrolled in the assemblage of the fuel cell act as the engineer claims? The examination of the spokesman's representation of his actants Latour calls a trial of strength.[87] Notice that what is put to the test (however it is achieved) is not Nature but a chain of association and the rhetorical claim of the engineer. For the test the engineer has enrolled as many allies as possible on his side: the control he has over the assemblage is valid only as long as his allies behave as he claims. That his actants act as claimed implies that natural elements – oxygen molecules, electrons, rare metals – possess agency as much as the human actants the engineer speaks for.

Thus Latour maintains a symmetrical description over both Nature and Society: the formation and construction of natural elements and natural order and societal elements and societal order are described by the same ontology. That Latour maintains that non-human actants have agency is the result of the failure of previous theories of sociologies of science.[88] The 'Strong Program for the Sociology of Knowledge' proposed to explain both successful and unsuccessful science by societal factors.[89] But Latour argues that this argument presupposes the society that is supposed to come from science and technology, effectively making the privileging of the social element a circular argument.[90] Therefore, Latour argues, both societal and natural factors must be

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[87] Latour (1987: 78).

[88] Lenoir (1994: 124-25): "The semiotic turn enters in *Science in Action* with the introduction of 'actors' and 'actants.' Latour proposed this new ontology, you all recall, in order to get out of the apparent asymmetry of the symmetry principle in the original Strong Programme for the Sociology of Knowledge. The first symmetry principle proposed to apply the same sorts of explanation to good and bad science. Rather than attributing the cause of closure of debate to nature in the case of truth, and to social factors in the case of error, both debates were to be conducted in light of the same sociological investigation of negotiation, interpretive flexibility, problems of replicability, etc. The problem with this, according to Latour, is that the only actors are human actors. Nature and other nonhuman actors, such as machines, never enter in as coparticipants and allies in the debates. The second symmetry principle, the generalized symmetry principle due to Michel Callon, overcomes this problem by not privileging the social; nature and society are explained in the same terms through some well-known and entertaining Janus-faced acrobatics. Debates are closed through enrolling allies and extending links in networks, and some of the allies are nonhuman actants."

[89] See Barnes, Bloor, Henry (1996) for an introduction to the Strong Program, originally developed in the 1970s.

[90] Latour (1987: 132-144) contains a version of this argument, but the best place for Latour's extended argument against the Strong Program is Latour (1988).

treated symmetrically with the same ontological description. This ontology is Latour's actors and actants and their process of enrolling allies in assembling a network constitutive of both Nature and Society. Actors are constantly in the process of translating, enrolling and binding claims into a networked assemblage of actants.

In summary Latour's *Science in Action* presents a picture of science as an assemblage drawn together from various networks. Networks and assemblages are the business of translating, enrolling, and binding semiotic and material elements. The nodal points of the networks are allies enrolled in the network whose durability is their ability to resist various trials; the nodal points may also be obligatory passage points for networked claims. Science-in-the-making is the process of enrolling allies and extending the network by the strategy of interessement; made science is the existing networked structure. Scientists defend their networked claims by pointing to its historicized elements, which serve as obligatory passage points for historically subsequent claims. To disassemble the network is to dissect, analyze, and read the constructed elements of the network. Latour considers how a skeptic might dissect the semiotic and material assemblage of a scientific claim:

> What is behind the claims? Texts. And behind the texts? More texts, becoming more and more technical because they bring in more and more papers. Behind these articles? Graphs, inscriptions, labels, tables, maps, arrayed in tiers. Behind these inscriptions? Instruments, whatever their shape, age and cost that end up scribbling, registering and jotting down various traces. Behind the instruments? Mouthpieces of all sorts and manner commenting on the graphs and 'simply' saying what they mean. Behind them? Arrays of instruments. Behind those? Trials of strength to evaluate the resistance of the ties that link the representatives to what they speak for. It is not only words that are now lined up to confront the dissenter, not only graphs to support the words and references to support the whole assembly of allies, not only instruments to generate endless numbers of newer and clearer inscriptions, but, behind the instruments, new objects are lined up which are defined by their resistance to trials. Dissenters have now done all they can do to disbelieve, disaggregate and disassociate what is mustered behind the claim.[91]

This network can be reduced to its systematic elements in such a way that produces a

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[91] Latour (1987: 79).

sociological analysis of the strategy of enrollment; for Latour sociological analysis proceeds from following the actor's development of the network.

Science in Action was criticized on several accounts. Sociologists criticized Latour's Machiavellian view of politics he ascribed to scientists; for sociologist critics Latour described a society similar to Thomas Hobbes' *bellum omnium contra omnes*, a description of society which sociologists often take as their foil.[92] Others criticized Latour's increasing reliance on the semiotics theory of A.J. Greimas in his more recent publications: "Latour also points out that the semiotics he is using has a certain ontological weakness; he just never specifies what that weakness is—namely, its reliance on a structural ontology of the world homologous to the stories scientists tell."[93] Despite the criticisms, Latour's work in *Science in Action* is the major theoretical statement of Actor-Network Theory (ANT). This sociological theory has continued to attract the work of other scholars. A short introduction to other important works of this type of sociology of science include works by Latour (1988, 1993, 2005), Law and Hassard (1999), and Law (2009). Much of the debate about ANT since *Science in Action* has moved away from its application to science studies towards its philosophical consequences and its view of social phenomena. Many studies which now employ ANT or elements of its sociological approach are sometimes called after-ANT studies.

My study too may be called 'after-ANT' because I employ many ANT concepts without embracing its broader critique of sociology. ANT provides a useful sociological tool for this dissertation because it describes the circulation and emergence of information within organizational systems in a sociological way. The foremost question we confront is how and why Hellenistic scientists adopted theories from other sciences to their own: the very question regarding the circulation and emergence of information ANT claims to be able analyze.

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[92] See the strident criticism of Amsterdamska (1990) and the more muted critique of Barnes, Bloor, Henry (1996: 114-116). Forman (2007: 75.n19) has a complete list of reviews of Latour (1987).
[93] Lenoir (1994: 129.n29).

1.5 SYNTHESIS

The theoretical tools at the disposal of this study are now clear: (1) a notion of the particular domain of a science; (2) a philological orientation to words adapted from one domain into another; (3) a sociological account of the circulation of ideas between domains, guided by the *Normung* of domain-specific words. We are ready to proceed to our case studies in detail.

INNOVATION

Chapter 2: Herophilus' Pulse Theory

In this chapter I argue that Herophilus adopted elements from musicians and musical theorists to describe anatomical phenomena that led to the emergence of a materio-semiotic object, the pulse. I show that Herophilus' account of pulse rhythms depends on the concept of the primary time-unit, developed by Aristoxenus of Tarentum. I show that Herophilus measured the frequency of the pulse by using a Greek concept of normative time via an Egyptian in-flow water-clock. Herophilus' conception of the pulse proceeds by a strategy of naturalization. The ideological consequence of Herophilus' pulse theory is Rationalist medicine.

2.1 HEROPHILUS' PULSE THEORY

2.1.1 Problematizing Scientific Novelty

Herophilus of Chalcedon, *ca.* 325-255 BCE, a Greek colonist from Bithynia to Egypt, was the first Greek doctor to isolate pulsation to the arteries and to use the pulse as a diagnostic tool.[1] Herophilus' pulse system could have been an isolated system, without connection to other elements, and might soon have been ignored and fallen apart. Latour's (1987) description of scientific networks as presented in chapter 1.4 stressed how new concepts, objects, or ideas in science draw their strength from their association with known concepts: they are networked into the assemblage of scientific concepts. The reality of the object or usefulness of the concept is the relative strength with which it is tied to objects recognized or concepts shared by the group of fellow scientists. Like any new science then, Herophilus' work on arterial pulsation is problematic: he was working with objects unused by previous physicians. To say that Herophilus was the first to

[1] See von Staden (1989: 26-29, 36-50) for a biography of Herophilus. Herophilus frr. 144-188b vS contain doctrines on the physiology of the vascular system and pulse theory. I use the term 'fragment' in a loose sense: von Staden's (1989) collection assembles testimonia concerning Herophilus' writings and doctrines and only a few testimonia quote verbatim Herophilus' own writings.

identify that pulsation is unique to the arteries is therefore a recognition that *at the time of his discovery* Herophilus' idea needed support from other concepts used within his social group of doctors. Novelty is always problematic within Kuhn's (1996) "normal science".[2] To address how Herophilus' work on arterial pulsation take its form and why it does not fall apart we must consider Herophilus' strategies of *interessement*: these are the strategies to interlace and bind new concepts with social goals of individuals (so as to produce allies) and with the known concepts and objects of nature.[3] In accord with the ANT's principle of a double symmetry, we are looking for an account operative on both a social and a natural level.

First, let us consider the social phenomena. The theory of arterial pulsation links the arteries with the heart, since the pulsation of the arteries is perceptible but the action of the heart is not. But if arterial pulsation is a consequence somehow of the timing of the beat of the heart, the physiology of a hitherto unobservable organ is perhaps observable by examination by arterial pulsation. More broadly then, arterial pulsation reveals the status and condition of the interior of the body.[4] Herophilus' work on arterial pulsation consequently belongs in (what the Empiricists would later name) the Rationalist tradition, as I will argue in 2.4.3. To investigate arterial pulsation is therefore part of the broader research program of Herophilus to open the body.

Opening the body may be socially useful for physicians. The promise of research medicine is a therapy of disease grounded in a theoretical understanding of *physis* which underlies pathological phenomena. The Empiricists reject this promise of research medicine because it promotes the researcher's aims at the expense of the actual treatment of the patient. Since the early Empiricists were often former Herophileans, it seems likely that they rejected the Herophilus' vision of medicine, his belief in better therapy

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[2] See chapter 1.2.3 for discussion of Kuhn (1996).

[3] See chapter 1.4 for discussion of Callon's (1986) concept of *interessement* within ANT.

[4] In chapter 4.3.2 I will read the debate between the Rationalists and the Empiricists as, from the Empiricist perspective, a debate over the role of the physician, and, from the Rationalist perspective, a debate over the interior of the body, where the Rationalist goal was to break down the divide in the Empiricist claims between a knowable outside and an unknowable inside. Latour's (1987) blackbox can be understood either as a fact to be constructed or deconstructed, as shown in chapter 1.4. By opening the body the Rationalists rejected the Empiricist claim that the workings of the body are essentially unknowable: the Rationalists thereby deconstruct the blackboxed 'fact' of the Empiricists.

through improved understanding of *physis*. If the promise of research medicine can be attained, the physician will have justified his methodological approach to medicine. Since the cultural aim and methodological investigation of *physis* are aligned, the promise of research medicine conforms to Lloyd's thesis about the interrelation of aim and method in Greek science. Therefore, also in accord with Lloyd's thesis, the promise of research medicine is socially useful for physicians because it allows them to avoid the social polemic on second-order questions of Greek science. It is therefore to the social benefit of the community of doctors to invest in theories of the body that support a therapy based on *physis.*

The twin legs of useful therapy and the investigation of *physis* undergird the social advancement of research physicians. If other physicians can employ the theory of arterial pulsation for therapeutic purposes, Herophilus will be able to tie his research to the social advance of medical research. The social group Herophilus can attempt to enlist as allies is therefore broader than the social group of research physicians, a fairly small and narrow group: by making arterial pulsation useful for therapy, Herophilus can increase the number of physicians invested in his methodological model of medical research. If everyday medical practitioners, nurses, and many other medical technicians employ a therapy based on arterial pulsation, they too become invested in the investigation of *physis*. Therefore it is to Herophilus' personal social advancement and that of his model of research that he detail a therapeutic purpose for his construction of the vascular system which isolates the pulsating faculty to the tunics of the arteries alone.

Second, let us consider Herophilus' strategies for *interessement* with natural phenomena, or naturalization. I use 'naturalization' in two senses. First, in the parlance of genealogical scholarship, natural objects are called "givens" and assumed as *a priori* facets of the world.[5] Insofar as the phenomena of time or anatomy (Herophilus' chosen natural phenomena) were natural and thus givens for Herophilus, any attempt to undergird the reality of pulse by using them is a strategy of naturalization. Second, naturalization is a strategy of extending the domain of nature, *physis* proper. In an

[5] Flemming (2000: 5). See also chapter 1.4 for discussion of Nietzschean geneaologies.

important essay G.E.R. Lloyd (1991b) has argued that 'nature' was invented by intellectuals of the Classical period, the philosophers and scientists who argued against magicians.[6] For these thinkers *physis* was the collective of material objects (as opposed to the category of the supernatural). Consequently, Hellenistic period scientists' appeal to *physis* is an appeal to a unified conception of nature whose attributes under one science might be recognized in another science.

Herophilus' *interessement* strategy of naturalization might therefore appeal to existing phenomena recognized both within the science of medicine and within other contemporary sciences of the Hellenistic period. Herophilus intertwined the pulse in anatomical terms with the physical phenomena of artery: its expansion, dilation, hardness, and other properties. Herophilus also attempted to link pulse to the phenomena of time measured both by musical rhythm and by water-clock.

2.1.2 Herophilus' Arterial Motions

The pulsating artery stands at the center of Herophilus' vision of pulse theory. Herophilus distinguished two arterial motions. The artery moves outward toward the physician's touch in a motion called διαστολή, "dilation"; it moves inward again away from the touch in a motion called συστολή, "contraction".[7] (Contemporary Western biomedicine uses the transliterated terminology of *diastole* and *systole* in reference to the movement of the artery, but uses the meanings of *dilation* and *contraction* in reference to the heart's pumping motion.) In contrast to contemporary Western biomedicine, there

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[6] Lloyd (1991b) is a published account of Lloyd's inaugral lecture at Darwin College in Cambridge and, unfortunately, is consequently published without footnotes or references. Much of Lloyd's discussion implicitly references his previous works.

[7] Appendix A shows that our knowledge of Herophilus' pulse theory is largely filtered through Galen's treatises on pulse; I will therefore occasionally distinguish Galen's view of pulse theory from Herophilus' in the footnotes of this chapter. For example, while Herophilus identified only two arterial motions in the cycle of arterial pulsation, Galen and later Greek physicians identified two further pauses associated with the cycle of arterial dilation and contraction: the pause or rest following dilation was called ἡ ἐκτὸς ἠρεμία "external rest" (because it happened at the peak of the artery's outward expansion toward the touch of the physician); the pause or rest following contraction was called ἡ ἐντὸς ἠρεμία "internal rest" (because it happened at the nadir of the artery's inward contraction away from the touch of the physician). Not all physicians agreed that contraction, the inward movement of the artery, was perceptible to touch; Galen only learned to feel it after many years of practice (cf. Herophilus frr. 159, 160 vS), but Herophilus and the Herophilean sect (αἵρεσις) believed that contraction was readily perceptible to touch. Due to differences in

was no attempt in Greek pulse theory to correlate the heart's pumping motion with arterial motion. Herophilus thought only of the artery, not the heart.

Praxagoras, Herophilus' teacher, was the first Greek to discover that only arteries pulse. "To pulse" in Greek, *σφύζειν*, was originally used to indicate violent motion and "pathological symptoms associated with, for example, fear and fever, not the normal vital function of the pulse".[8] Praxagoras and Herophilus applied the word exclusively to the involuntary motion of the arteries and most other doctors followed, even as *σφύζειν* retained its original sense for several centuries in ordinary language.[9] But Praxagoras conflated several types of involuntary movement, claiming that "tremor" *τρόμος*, "spasm" *σπασμός*, and "palpitation" *πάλμος*, as well as "pulse" *σφυγμός* were likewise involuntary movements of the arteries and differed only by size, not kind.[10] Herophilus refined Praxagoras' discovery and attributed Praxagoras' other involuntary motions to the muscular and nervous systems; for Herophilus then "tremor" *τρόμος*, "spasm" *σπασμός*, and "palpitation" *πάλμος* became involuntary pathological motions of the muscular and nervous systems. Consequently, Herophilus was the first to identify *σφυγμός* as an involuntary and natural movement unique to the arteries; thus Herophilus was the first Greek physician to determine that arteries alone pulsate naturally.

While Praxagoras held that the arteries pulsate of their own accord, Herophilus maintained that the arteries pulse from two sources: from some connection to the heart and from a faculty flowing to them through their tunics. Galen recorded two important testimonia regarding Herophilus' views on the source of the pulsation of the arteries.

> *ἐνίων δὲ σφύζειν μὲν αὐτοῦ, τοῦ χιτῶνος αὐτῶν διαστελλομένου τε καὶ συστελλομένου, καθάπερ ἡ καρδία, τὴν δύναμιν δὲ οὐκ ἐχουσῶν σύμφυτον ἢ τοῦτο δρῶσιν, ἀλλὰ παρὰ καρδίαν λαμβανουσῶν. ἧς γνώμης ἔχεται καὶ Ἡρόφιλος.*
>
> Others [sc. against the opinion of Praxagoras that the arteries pulse from their own innate faculty] held that [the arteries] pulse, as their tunic itself dilates and contracts, just as the heart, although not by having an innate faculty do they do

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their views about the parts of the cycle of arterial pulsation, Galen often struggled to understand Herophilus' theories; see Appendix A.

[8] Von Staden (1989: 268).

[9] See LSJ *σφύζω* 3.

[10] Von Staden (1989: 271).

this but by taking pulsation from the heart. Herophilus too held this opinion.[11]

Herophilus thought that the tunic of the arteries is the source of the perceptible dilation and contraction of the arteries; they do not pulse from their own faculty but from a faculty that they draw from the heart. Galen elsewhere recorded that Herophilus believed that the tunic of arteries is six times as thick as that of the veins.[12] It is a speculative but possible conclusion that Herophilus supposed that the composition of the arterial tunic allowed pulsation drawn from the heart. (If so, the thinner and less visible venal tunic may have offered Herophilus a reason why the veins do not pulse too.) Galen recorded a slightly more informative testimonium in another passage:

> τοῖς δὲ περὶ τὸν Ἡρόφιλον ἀρέσκει τὰς ἀρτηρίας συνεχεῖς οὔσας τῇ καρδίᾳ διὰ τῶν χιτώνων ἐπιῤῥέουσαν ἔχειν τὴν παρ᾽ αὐτοῖς δύναμιν, ᾗ χρώμεναι παραπλησίως αὐτῇ τῇ καρδίᾳ διαστελλόμεναι μὲν ἕλκουσι πανταχόθεν, ὅθεν ἂν δύνωνται, τὸ πληρῶσον αὐτῶν τὴν διαστολήν, συστελλόμεναι δὲ ἐκθλίβουσι.
>
> Herophilus and his followers hold that, since the arteries are continuous to the heart, they have a faculty to them flowing through their tunics. By employing this faculty similar to the heart itself, when in dilation they draw from everywhere they can that which fills their dilation, and in contraction squeeze it out.[13]

So Herophilus believed that the faculty of arterial pulsation is transmitted through the tunics of the arteries. Later Herophileans' definitions of the pulse explicitly included the heart with the arteries in dilation and contraction,[14] but it is unclear whether Herophilus too believed that dilation and contraction appeared in the heart. Galen's testimony states that the faculty of pulsation was "similar to the heart", presumably a reference to a similarity in the timing of the beat of the heart with the pulsation of the arteries. Herophilus did not consider the heart a pump and so did not maintain that the movement of the blood, *pneuma*, or whatever is contained in the arteries was responsible for

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[11] Galen *de pulsuum differentiis* 4.2, 8.702-3K = Herophilus fr. 155 vS.

[12] Galen *de usu partium* 6.10, 3.445K = 1.325 Helmreich = Herophilus fr. 116 vS.

[13] Galen *de pulsuum differentiis* 4.6, 8.733K = Herophilus fr. 144 vS. While τοῖς δὲ περὶ τὸν Ἡρόφιλον is an ambiguous phrase that could mean only "the followers of Herophilus" and thus exclude Herophilus himself, the opinion in this passage is parallel with the opinion ascribed to Herophilus in Herophilus fr. 155 vS. Hence I follow von Staden (1989: 322) in translating τοῖς δὲ περὶ τὸν Ἡρόφιλον as "Herophilus and his followers".

[14] Herophilus fr. 157 vS; see also von Staden's (1989: 447) list comparing the theories of Herophileans on the pulse.

transmitting the arterial pulse. Furthermore, in Herophilus' theory the muscular tissue of the heart cannot produce the same involuntary motion as the arteries, because the involuntary motions of the heart must be specific to the muscular system, namely tremor, spasm, or palpitation.[15] Galen elsewhere suggested that Herophilus conceived of the use of the pulse for diagnosis and prognosis without requiring pulse in any other body part except the arteries.[16] Therefore, for Herophilus the faculty of pulsation was specific to unique organs of the vascular system – the arteries – and not to any fluids they may carry.

Herophilus ascribed four generic *differentiae* to the pulsating artery. Galen, in the midst of an argument that Herophilus did not use the later generic *differentia* 'fullness' among his descriptions of the pulsating artery, quotes Herophilus' description of arterial motion from Herophilus' treatise *On Pulses*:

> πρῶτον μὲν ἐπιφέρων εὐθύς φησιν ὠδί – γράψω γὰρ τὴν ῥῆσιν ὅλην … καθ' ὅλου μὲν οὖν δοκεῖ διαφέρειν σφυγμὸς σφυγμοῦ πλήθει, μεγέθει, τάχει, σφοδρότητι, ῥυθμῷ. ἐκ τοῦ κατὰ ταῦτα διαφέρειν φανερὸς γίνεται ἐνίοτε ὅ τε οἰκεῖος καὶ οὐκ οἰκεῖος. φαίνεται δὲ διαφέρειν καὶ ἐπιγινώσκεσθαι καθόλου μὲν ἕτερος ἑτέρου σφυγμὸς, ὡς εἴρηται, ῥυθμῷ, μεγέθει, τάχει, σφοδρότητι. εἰ δὲ ἐν τῷ αὐτῷ ῥυθμῷ φαίνεται διαφέρειν ἕτερος ἑτέρου σφυγμὸς σφυγμοῦ τάχει, μεγέθει, σφοδρότητι.
>
> First introducing the subject [Herophilus] says as follows – for I will write down the entire passage … "In general pulse seems to differ from pulse in amount, size, speed, vehemence, and rhythm. From their differences in these respects pulse at times appears proper and [at times] not proper. One pulse seems to differ and be recognized generally as different from another, as was said, in rhythm, size, speed, vehemence. If in the same rhythm one pulse seems to differ from another in speed, size, and vehemence."[17]

Later doctors added more *differentiae* of the pulse to Herophilus' initial assessment, but it appears that Herophilus analyzed the movement of the artery in terms of four categories. Herophilus' first sentence does indeed list five *differentiae* but two sentences later Herophilus lists only four *differentiae*: size, speed, vehemence and rhythm. Galen believed that Herophilus only used these four,[18] but it is possible that Herophilus intended

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[15] Galen *de placitis Hippocratis et Platonis* 6.1 = Herophilus fr. 153 vS.
[16] Galen *de pulsuum differentiis* 4.2, 716K = Herophilus fr. 148 vS.
[17] Galen *de dignoscendis pulsibus* 4.3, 8.959-60K = Herophilus fr. 162.77-86 vS.
[18] In Herophilus frr. 163a, 163b Galen transmits the view of Archigenes, a leading theoretical physician *fl.* 100 CE, that Herophilus uses other specific *differentiae* between pulses – regularity, irregularity, evenness,

the fifth *differentia*, "amount", to have some connection to frequency, which Herophilus measured with a water-clock, as described in 2.2.2 below, rather than with fingers alone.

Herophilus developed normative pulses for four different age-groups: newborns, children and teenagers, adults, and the elderly.[19] Von Staden (1989) points out that the implication of several Herophilean fragments is that Herophilus measured pulse in terms relative to that of the age-group.[20] The age-groups determine the normative *differentiae* of the pulse. Herophilus' *differentiae* of pulses are therefore limited to his classification of age-groups. Thus, a newborn has a normative pulse described in terms of size, speed, vehemence, and rhythm; a teenager has a normative pulse described in separate terms of size, speed, vehemence, and rhythm; and so on for each group. The Herophilean physician first placed the patient into an age-group before the determining the generic characteristics of his pulse.

Given that Herophilus believed pulse to be composed of two arterial motions, dilation and contraction, which did Herophilus mean to be measured by his *differentiae*? Herophilus' procedure for constructing a normative pulse rhythm, analyzed in chapter 2.2.1, begins from the dilating artery.[21] Let us therefore proceed by assuming that Herophilus thought the dilation was the most important movement.

We imagine Herophilus feeling the forearm of a patient, already placed in one of the four age-groups, in order to classify the four *differentiae* of the patient's pulse. He felt how much the artery moves outward to him; this is the *size* of the pulse. Herophilus classified pulse sizes as 'sufficient', 'good-sized', and 'remarkable'.[22] Herophilus felt

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and unevenness – although without treating them as generic differences between pulses as size, speed, vehemence, and rhythm.

[19] Herophilus fr. 177 vS.

[20] Von Staden (1989: 285): "Compared to the pulse of an adult, the child's pulse might be small but relatively speaking, i.e. in relation to the circumference of a child's artery, it is as 'adequate in size' or 'good-sized' as the adult's pulse."

[21] Herophilus fr. 183.8-9 vS: *πρῶτον χρόνον αἰσθητὸν ὑποθέμενος ἐν ᾧ διαστελλομένην εὕρισκε τὴν ἀρτηρίαν* … "Supposing that the perceptible time-unit in which he found the artery dilating was primary …" Yet Galen was not entirely sure whether Herophilus thought dilation or contraction was more important: in Herophilus frr. 157, 158 vS Galen at last decides that Herophilus meant contraction to be the active motion. Herophilus fr. 183 vS shows that Galen is likely mistaken.

[22] See von Staden (1989: 285-86). Three different testimonia show these descriptions. (1) Galen *de dignoscendis pulsibus* 2.3, 8.869K = Herophilus fr. 184 vS: *μικρόν γ' οὖν λέγουσι τὸν τοῦ παιδὸς σφυγμὸν, Ἡροφίλου μηδεπώποτε μικρὸν εἰρηκότος, ἀλλὰ ποτὲ μὲν ἱκανὸν τῷ μεγέθει, ποτὲ δὲ*

how quickly the artery dilates toward his touch; this is the *speed* of the pulse. Herophilus classified pulse speeds as 'regular', 'fast', and 'slow'.[23] Herophilus felt the strength of the artery's motion in dilation; this is the *vehemence* of the pulse. There is no evidence how Herophilus classified pulse vehemences, although later physicians classified them as 'strong' or 'weak'.[24] Finally, Herophilus felt the length of time of the dilation and compared it to the length of time of the contraction; this is the *rhythm*.

Clearly the most important factor in Herophilus' analysis of the pulse is his ability to perceive by touch. The Herophilean physician must use his fingers alone to sense and analyze four charateristics in the motion of the pulsating artery, as well as to distinguish between the artery's dilation and contraction. This ability requires time and training. The skill necessary in the doctor's touch was almost certainly part of the repetoire of clinical procedures and knowledge taught *in situ* by physicians to their students: there is no record in the surviving fragments of Herophilus' *On Pulses* of written instructions for feeling the pulsating artery.[25] It remains unclear how Herophilus himself acquired this sophisticated ability to perceive arterial characteristics by touch.

ἀξιόλογον, ἤ πως οὕτως ὀνομάζοντος. "Well they at any rate call the pulse of a child small, but Herophilus never called it small, but sometimes named it sufficient in size, sometimes remarkable, or something similar." (2) Galen *synopsis de pulsibus* 8, 9.453K = Herophilus fr. 180 vS: *τὸν γοῦν τοῦ παιδὸς σφυγμὸν ὁ μὲν Ἡρόφιλος ἱκανὸν τῷ μεγέθει φησὶν ὑπάρχειν, ὁ δ' Ἀρχιγένης μικρόν.* "The pulse of the child at any rate Herophilus says is sufficient in size, but Archigenes [says it is] small." (3) Galen *de dignoscendis pulsibus* 2.2, 8.853K = Herophilus fr. 181 vS: *Ἡρόφιλος γοῦν ποτὲ μὲν εὐμεγέθη τὸν σφυγμὸν τοῦτον ὀνομάζει.* "Herophilus at any rate calls this pulse [sc. a child's pulse exceeding Galen's moderate pulse] good-sized."

[23] See von Staden (1989: 284-85). Pliny *NH* 11.89.219 = Herophilus fr. 186 vS: *arteriarum pulsus in cacumine maxime membrorum evidens, index fere morborum, in modulos certos legesque metricas per aetates, stabilis aut citatus aut tardus, discriptus ab Herophilo medicinae vate miranda arte*. "The pulse of the arteries is clear chiefly at the end of the limbs; it is nearly a marker of diseases and was divided into fixed meters and metrical laws by age, <as> regular or fast or slow, by Herophilus a prophet of medicine with wonderous skill."

[24] Von Staden (1989: 274-75). See also Galen's description of vehemence at *de pulsuum differentiis* 1.3, 8.501K: *καὶ μὲν δὴ καὶ τόνου πὼς αὐτὴν ἔχειν ἀναγκαῖον, ὥστε ἢ μόγις καὶ ἀρρώστως, ἢ ἑτοίμως τε καὶ εὐρώστως ἐνεργεῖν*. "It is further necessary that it have tension, either weak and faint, or readily and strongly active."

[25] Strikingly there is no explicit discussion in any work of Greek pulse theory about the clinical procedure for feeling a patient's pulse. The closest an ancient author comes to discussion of a clinical procedure occurs in Galen *de pulsibus ad tirones* 8.454K: he merely states that the doctor best determines a patient's pulse by feeling the arteries in the temples, wrist, or the instep of the foot. Galen does not explain essential aspects of the clinical procedure, such as how the physician ought to use his fingers or where the physician ought to place them on the artery. Skills of touching were almost certainly passed from teacher to pupil in bedside training.

2.2 TIMING ARTERIAL PULSATION

Since the *differentiae* of size, vehemence, and speed are given subjective measurements and descriptions, the more objective criterion in Herophilus' treatment of the pulse is the timing of arterial pulsation. The *differentia* 'rhythm' certainly covers pulse timing and it is possible that 'amount', the fifth *differentia* Herophilus mentioned, also covers pulse timing. Herophilus appears to have approached the measurement of pulse timing in two different ways: through appropriating Aristoxenus' theory of musical rhythms and by employing a water-clock to measure pulse frequency. We thus have two separate traditions of Herophilus' application of time measurement to pulses.

A historian faces two problems here. First, which 'solution' to the measurement of the pulse by timing did Herophilus intend to be correct? This is a problem of authorial intent. Second, which 'solution' did Herophilus develop earlier? This is a problem of historical chronology. We might collapse the two problems into one and argue that Herophilus' treatment of the problem of pulse rhythm underwent a progressive development: those Herophilean fragments which show conceptual problems and technical difficulties must date earlier than those Herophilean fragments which show superior handling of the technical material; and Herophilus intends his latter, more technically competent material to be the correct solution. But the suggestion lacks evidence to support it and is open to criticisms of Whiggish historiography.

Whiggish historiography was an influential view of progress in thought and society.[26] Originally a historiographical strategy of eighteenth-century British Whig political historians, it became a popular method to write the history of science in the late nineteenth and early twentieth century. Whiggish historiography using modern science as a benchmark takes present thought to be the culmination of tradition; historical science is correspondingly read for how close those past theories and ideas approximate present

[26] The *locus classicus* for discussion of Whiggism is Butterfield (1931). See Jardine (2003) for a realist discussion of the reception of Butterfield and the historiography of science. See Barton (1994b: 8-17) for a relativist discussion of the trend of presentism in ancient science historiography. Chapter 5.2 discusses the historiographical question of realism and relativism in ancient science.

theories and ideas, which are assumed to be correct.[27] In a broader sense Whiggism is any historiographic principle by which historians give or explain chronological sequence to undated historical material according to its 'scientific progress' or, conversely, explaining a known dated sequence on the assumption that 'scientific progress' is occurring.

In the case of Herophilus' work on pulse rhythms, the appropriation of Aristoxenian concepts of musical rhythms better fits all phenomena relating to the timing of the pulse. The water-clock, on the other hand, is limited to the relative quantification of the pulse's dilation. Applying the scientific progress of Whiggish historiography to these results, we might insist that Herophilus' water-clock was an earlier (and failed) attempt to use the pulse for diagnosis, an aim better effected by Herophilus' later work with Aristoxenus' theory. Reading Herophilus' pulse timing with Whiggish historiography collapses the two problems of authorial intent and historical chronology: it assumes that Herophilus rejected his earlier solution of the water-clock for his later 'correct solution' of appropriating Aristoxenian musical rhythms. The flaws of this historiographical strategy are clear.

A different historiographical strategy comes from comparing the case of the fragments of Herophilus' pulse theory with the situation of Archimedean material to be discussed in chapter 3.2.2, where Archimedes had solved the same mathematical problem two times in the same treatise. Netz (2009a) has argued that our understanding of the Archimedean material gains more from the intertext of the technical details; and correspondingly he treats the ostensibly earlier half of the treatise as an intertext of the second half of the treatise, its presumably main, later version: this is a version of intertextuality$_R$ as described in 1.3.1 where the reader is figured as the modern historian. Using intertextuality$_R$ chapters 2.2.1-2 will consider Herophilus' fragments relating to the appropriation of Aristoxenian rhythms and to the report of Herophilus' water-clock as intertexts of each other. Hence intertextuality$_R$ is a historiographical strategy: the

[27] Whiggish historiography using modern science rapidly becomes to be writ in the dichotomy of realism versus relativism. Consequently one historical idea triumphs over another *because it is the right idea* (that is, it is the present idea). History's winners are the prophets of the present.

question of chronological priority between Herophilus' fragments relating to the appropriation of Aristoxenus' theory and Herophilus' fragments relating to the water-clock is put into abeyance. By holding the chronological question in abeyance, intertextuality$_R$ offers instead a sense of the continuity and contrast between the two different sets of fragments.

The contrast between Herophilus' different theories will focus on the role of the quantitative measurement of time. I will show that Herophilus' timing of the pulse – whether analyzed by appropriated Aristoxenian rhythms or by water-clock – employs a normative concept of time, that is, measuring an event by discrete units of elapsed time.

2.2.1 Rhythms in Herophilus' Pulse-Theory

While Herophilus' innovative description of the timing of arterial motion as a system conforming to musical and metrical rhythm remained part of popular imagination until the end of antiquity,[28] there is scholarly debate about what sort of rhythm Herophilus used to describe pulsations. Wellman (1895) long ago suggested that Herophilus adopted his terminology and theory of rhythm from Aristoxenus of Tarentum, a late fourth-century student of Aristotle, who wrote influential accounts of harmonic theory and rhythmical theory.[29] Heinrich von Staden's opinion seems to have changed on this issue: in his (1989) collection of Herophilean fragments he doubts that Aristoxenus influenced Herophilus but in his (1996) article considers it possible.[30] I believe that Wellman is correct and will reargue the case.

First, Galen remarks that Herophilus' statements on pulse rhythms are difficult to understand because they presuppose the readers' heavy acquantaince with rhythm in musical contexts.

> διὰ τοῦτο γοῦν καὶ περὶ τῶν ῥυθμῶν ὅσα μὲν ἐχρῆν αὐτοὺς ἔτι παῖδας ὄντας ἐν τοῖς τῆς μουσικῆς διδασκαλείοις ἐκμαθεῖν, ταῦτ' οὐδόλως εἰς τὰ τῆς ἰατρικῆς συγγράμματα φέρουσι, τὸ τῶν ὀψιμαθῶν πάθημα πάσχοντες, οὐδὲ σιωπῆσαι δυνάμενοι, κἂν ἑτέρας ᾖ τέχνης. πῶς δ' ἀπὸ ῥυθμοῦ δεῖ σημειοῦσθαι, οὐκέτ' οὐδεὶς ἔγραψεν αὐτῶν. ἀλλ' Ἡρόφιλός γε τὴν ἐναντίαν ὁδὸν ἰὼν αὐτοῖς παραλείπει μὲν ἃ παρὰ τοῖς μουσικοῖς ἐχρῆν μεμαθηκέναι τὸν ἀξίως τῆς τέχνης

[28] See the reports of Censorinus and Martianus Capella in Herophilus frr. 187, 188a vS.

[29] I have not seen Wellman's (1895) account. See von Staden (1989: 278.n134) for further bibliography on the question of Aristoxenian influence.

[30] See von Staden (1989: 278-79) and von Staden (1996: 89).

> πεπαιδευμένον, ὡς ἐπισταμένοις δ' αὐτοῖς διαλέγεται, τὸ χρήσιμον εἰς τὴν ἰατρικὴν ἐξ αὐτῶν λαμβάνων. οἱ δ' ὅταν τὴν θαυμαστὴν ταύτην, ὡς αὐτοὶ καλοῦσι, τεχνολογίαν τὴν περὶ τῶν ῥυθμῶν διεξέλθωσιν, οὐκέτ' αὐτοῖς μέλει δεῖξαι, πῶς ἄν τις ἱκανὸς προγνῶναί τι δι' αὐτῶν, ἢ σημειώσασθαι γένοιτο.
>
> For this reason anyway whatever about rhythms of music they ought to have learned while they were still children in the schools they in no way bring to treatises of medicine, suffering the ill-effect of their late learning, nor can they keep silent, even if [the subject] belongs to another art. No one of them wrote how one ought to make meaning from rhythm. But Herophilus at least, going a route opposite to them, leaves out what someone worthily educated of the art should have learned from musicians, and speaks to them as if they understand, since he takes what is useful from them into medicine. But they, whenever they detail this amazing system [τεχνολογίαν[31]] – as they call it – about rhythms, they no longer care to show how one might sufficiently make prognoses or interpret through these things.[32]

The Galenic topos is the stupidity and poor education of his opponents; its form in the present passage is Galen's medical opponents' lack of knowledge about music.[33] Music is a different *techne* than medicine and Herophilus brought music into medicine to produce a system of medical rhythm. Galen's further point is that Herophilus' followers are so enchanted with his medical rhythms system that they cease to bother with predicting the course of diseases, the very purpose for which the system was developed. To understand Herophilus' medical rhythms system one needs to understand the technical language of both medicine and music.

This passage is one of many where Galen explicitly states that Herophilus' rhythmical language is drawn from ἡ μουσική, the *techne*, and οἱ μουσικοί, the practitioners of the *techne*. There are other parallels of diction between Herophilus' medical rhythm and musical rhythm. For instance, Herophilus compared dilation and contraction to the up-beat (ἄρσις) and down-beat (θέσις), respectively, of musical rhythm.[34] By Langslow's (2000) criteria of *Fachbezogenheit* and *Normung* as argued in

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[31] The word certainly does not mean its cognate, *technology*. Rather it seems to be a word associated with the comprehensive rhetorical nature of a *techne*. See Mansfeld (1998: 82.n290).

[32] Galen *de dignoscendis pulsibus* 2.3, 8.871-2K = Herophilus fr. 184 vS.

[33] Note the key term of second sophistic culture and intellegentsia, πεπαιδευμένος, in τὸν ἀξίως τῆς τέχνης πεπαιδευμένον.

[34] Herophilus fr. 183.3-7 vS.

chapter 1.3.2, the terms ῥυθμός, ἄρσις, and θέσις are technical language because of the specificity of their usage within a certain sociolect, the domain of practicing musicians and musical theorists. The technical terms point both toward the sociolect, the technical language of the *techne*, and the social group employing them, the *technitae*. Therefore the terms ῥυθμός, ἄρσις, and θέσις are part of the technical vocabulary of practicing musicians.[35]

Herophilus coopted the language of the sociolect of musicians for some purpose by employing these terms in a medical context. Langslow argues that one of the strengths of a technical language is the specificity of its use: the particularity of language use (*Normung*) is an act of categorization, specifying some object by particular reference. To compare *arsis* to dilation and *thesis* to contraction leads to the comparison between dilation and contraction in the manner similar to the comparison of *arsis* to *thesis*: the artery rises toward the physicians' touch in dilation like the up-beat, the artery falls away from the physician's touch in contraction like the down-beat. Thus the new conceptual *differentia* that Herophilus was able to specify by using the terminology of musicians is the ratio of dilation to contraction, that is, the rhythm of the pulse. The category of pulse rhythm was therefore founded on an analogy with the terminology of musical rhythm so as to describe as exactly as possible the new object.

But underlying Herophilus' project of categorization is the standard of measurement. While Herophilus now had physical objects, arterial dilation and contraction, to analogize to the elements of musical rhythm, *arsis* and *thesis*, he lacked a conceptual tool by which to measure the time of dilation and contraction. Aristoxenus of Tarentum's theory of rhythm offers the ability to solve this problem. Central to Herophilus' appropriation is Aristoxenus' concept of the 'primary time-unit.'

Aristoxenus in his *Elements of Rhythm* aims to provide an analysis of rhythm on the basis of empirical phenomena.[36] In his terminology, rhythm is composed of time-

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[35] See LSJ ῥυθμός I.1; LSJ ἄρσις III; LSJ θέσις VI.

[36] Most scholarship on Aristoxenus concerns his *Elements of Harmonics*, the major surviving work. Pearson (1990) is the best collection of evidence relating to Aristoxenus' rhythmical theory. See further accounts of Aristoxenus' rhythmical theory in West (1992: 224-5) and Gibson (2005: 77-98).

lengths and things that are capable of assuming rhythm are called ῥυθμιζόμενα, *rhythmizables*. In rhythm and rhythmizables Aristoxenus thus contrasts the notional and material properties, respectively, of rhythm in an Aristotelian manner. The smallest unit of time into which rhythmizables can be broken down is the πρῶτος χρόνος, "primary time-unit". While book 1 of Aristoxenus' *Elements of Rhythm* is lost, book 2 preserves an account of the primary time-unit.

> Time is divided by rhythmizables in each of its parts. There are three rhythmizables: speech, song, and bodily motion. Therefore speech will divide time by its parts, such as letters and syllables and words and all things of this kind. Song will divide time by its pitches, intervals, and concords. Bodily movement will divide time by its points and figures and [whatever else] if there is some such part of motion.
>
> Let be called a primary of time-units that capable of being divided by none of the rhymthziables, a diseme that measured twice by that <primary time-unit>, triseme [that measured] three times, a tetraseme [that measured] four times. In the case of the remaining magnitudes they will get their names in the same way.
>
> The meaning of the primary time-unit must be understood in the following way. One of the appearances that presents itself readily to perception is that the speeds of motions do not increase to an infinite degree, but are somehow fixed in arranged time-units, in which the parts of things that are set in motion are made. By things-set-in-motion I mean how the voice moves in speaking and singing and the body moves in signifying and dancing, moving the rest of such sort of movements.
>
> Since these appearances are so, it is clear that there is need that some of the time-units are the smallest [possible], in which the singer makes each note. The same account is clear concerning syllables and concerning signs.
>
> <The time-unit> in which two notes cannot be made in any way, nor two syllables, nor two signs, we will call this a primary time-unit [πρῶτον χρόνον]. How the senses will perceive this will be clear in the case of the schema of feet.[37]

Now speech, song, and bodily movement define separate elements of the rhythmizables: constituent parts are capable of assuming rhythm in relation to each other. Even these smallest parts must take some unit of time. The primary time-unit, πρῶτος χρόνος, is the amount of time coequal with the shortest elements within any rhythmizable. That is, the primary time-unit remains whole and unable to be divided into further rational units (i.e. non-fractional) because the elements of the rhythmizables themselves cannot be divided

[37] Aristoxenus *Elementa Rhythmica* 2.9-12, 6-8 Pearson.

into further rational units.

In Aristoxenus' example of speech, for example, the smallest rhythmizable unit is the letter. Since the primary time-unit will be dependent on the smallest rhythmizable, an entire sentence could thus be rhythmically analyzed as units of the primary time-unit: the rhythmic sequence of the sentence will consist of primary time-units, disemes (double the primary time-unit), trisemes (tripe the primary time-unit), and so on.[38] The sentence's rhythm exists as the relation of at least two time lengths: e.g. primary time-unit to primary time-unit, primary time-unit to diseme, etc. The units of rhythm, based on the primary time-unit, are therefore dependent on rhythmizables, human perceptions of the non-divisibile elements of empirical objects: language in this case.[39]

The length of time taken to pronounce a letter, a time that varies with each speaker, is the primary time-unit of spoken rhythm in Aristoxenus' example of speech. Thus in Aristoxenus' system the primary time-unit is not an absolute measurement: it will vary with the tempo applied to the medium of rhythm. The primary time-unit is like the beat of the tempo: the primary time-unit can be shorter if the speaker speaks quickly, or longer if the speaker speaks more slowly.[40] The primary time-unit is not an absolute length of time, only the time taken for the smallest divisible element of the rhythmizable.

We can distinguish between two different types of temporal measurements. The primary time-unit functions as what I will call normative time, measuring an event by the

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[38] The example of letters would seem to work better in Greek than in English, where homophones, heteronyms, silent letters, and variant pronunciations of vowels abound. Nevertheless, the example of letters assuming rhythm serves a literary point. Gibson (2005: 78-81) points out that Aristoxenus is at pains to distinguish himself from previous theories of rhythm: Plato, Aristotle, and earlier theorists assumed that syllables of speech were the primary object capable of assuming rhythm.

[39] Gibson (2005: 92): "The *chronos protos* [i.e. the primary time-unit] provides a term for a unit of measurement which has no particular association to melody, poetry, or dance. It establishes an atomic element from which rhythm can be built, functioning in a similar way as the *diesis* in some methods of harmonic theory. The difference, of course, is that the *diesis* is generally assumed to be (at least approximately) a quarter-tone, whereas the *protos chronos* has no standard measure and varies infinitely according to the tempo of the rhythm."

[40] Pearson (1990: 76): "A performer establishes the *tempo* of what he is going to play by deciding the length of the primary *chronos*, just as a musician today may fix the metronome setting at [quarter note] = 120, deciding that each [quarter note] will take half a second, a hundred and twenty to the minute." A modern musician can equally establish a tempo at half the speed: he sets the metronome at a quarter note = 60 so that each quarter note takes a second. The *protos chronos* remains the same but the tempo has changed.

duration of the primary time-unit. In Aristoxenus' example of the sentence, the speaker's spoken letter (the primary time-unit) functions as the normative measurement by which other temporal phenomena are counted. The duration of the *protos chronos* of the spoken letter establishes the norm against which the sentence is measured. By contrast, the length of passing time the speaker takes to say the sentence I will call standardized time. (I am deliberately avoiding the misleading terms 'relative' and 'absolute' in describing the function of time; 'normative' and 'standarized' are not synonyms for 'relative' and 'absolute'.) Suppose then that two speakers utter the same sentence. Each speaker will use a letter as the same primary time-unit but one speaker will express the sentence faster than the other speaker: there is one normative time, the primary time-unit, and thus one rhythm, but there are two different standardized times, the passing duration of their utterances, and thus two tempos.

Herophilus used Aristoxenus' primary time-unit in his pulse theory. Several Herophilean fragments employ the term of 'primary time-unit'.[41] Moreover, the case for Herophilus' appropriation of Aristoxenus' rests on more than similar terminology: Herophilus appears to have actively employed Aristoxenus' theory of the 'primary time-unit' in his writings on pulse rhythm. Galen notes that Herophilus used a unit of measurement to measure all parts of arterial pulsation:

> *πῶς οὖν Ἡρόφιλος πρῶτός τινα πρὸς αἴσθησιν ὑποτίθεται χρόνον, ᾧ τοὺς ἄλλους μετρῶν ἢ δυοῖν, ἢ καὶ τριῶν, ἢ καὶ πλειόνων εἶναι φάσκει, ἤτοι τελέων τε καὶ ὡς αὐτοὶ καλοῦσιν ἀπαραύξων, ἢ καὶ ἀπηυξημένων ἐπ' ὀλίγον, ἢ ἐπὶ πλεῖον, ἢ ἐπὶ πλεῖστον;*
>
> How therefore was Herophilus first to establish some time-unit in relation to sense-perception, by which he, in measuring the other <time-periods>, claimed that they consist either of two or three or more [of these units], or [that these units] are both perfect and not-subject-to-increase, as they themselves call them, or decreased a little or a great degree or the greatest degree?[42]

Herophilus constructed some time-unit (Galen identifies this a 'primary time-unit', *πρῶτος χρόνος*, later in the passage[43]) and used it to measure the time of dilation and

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[41] Herophilus frr. 178.2, 183.25 vS.

[42] Galen *de dignoscendis pulsibus* 3.3, 8.913K = Herophilus fr. 174.1-5 vS. See Appendix A for more on Galen's disagreements with Herophilus.

[43] Galen *de dignoscendis pulsibus* 3.3, 8.915K.

contraction: a pulse rhythm therefore might consist of two or three primary time-units. There is a common temporal measurement to all parts of the cycle of arterial dilation and contraction. The time of other dilations and contractions measured in relation to the initial time-unit produce either multiples of two or three, Aristoxenus' musical disemes and trisemes. The time length of further dilations and contractions measured in relation to the initial time-unit produce fractions of varying complications and thus yield the rhythm of arterial dilation to contraction.[44]

Therefore, the fragments of Herophilus' theory of pulse rhythms show a correspondence of situational context and diction to Aristoxenus' rhythmical theory. Herophilus' usage of the term 'primary time-unit' and his employment of Aristoxenus' theory of the primary time-unit indicate his appropriation of the terminology and theory of musicians. The correspondence of situational context and diction between two texts is intertextuality$_A$ as shown in 1.3.1. Herophilus has marked his appropriation of

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[44] It seems clear that the passage must refer to fractions of some sort but what kind precisely is not at all clear, since it is difficult to know what Galen's Greek means here: *ἤτοι τελέων τε καὶ ὡς αὐτοὶ καλοῦσιν ἀπαραύξων, ἢ καὶ ἀπηυξημένων ἐπ' ὀλίγον, ἢ ἐπὶ πλεῖον, ἢ ἐπὶ πλεῖστον*. The terminology of fractions is confused. For instance, *τέλεος* in arithmetic refers to perfect numbers, that is, a number whose divisers sum up to the number (e.g. 6 = 3+2+1); see LSJ *s.v.* I.5.b. It *may* mean that here. Although a ratio made of a numerator of a perfect number and a divisor of a perfect number can always be reduced further (in the example of 6:3 this can be reduced to 2:1), there is another testimonium (Herophilus fr. 177 vS) where multiple primary time-units yield pulses that are equivalent in ratio yet differ in temporal length. For example, 1:1 of a child's pulse rhythm is equivalent to 2:2 of an adult's pulse rhythm but the adult's pulse lasts twice as long as the child's. As long as Herophilus talks of primary time-units which measure others, one may apparently produce multiples of the time-unit in relation to multiples of the time measured.

The next term about fractions, *ἀπαραύξων*, is even more confusing, since it appears only in this passage of all of Greek literature. LSJ *s.v.* defines it as "not subject to increase" but calls the term itself "dubious." There is an entry *s.v.* in the 1831 Stephanus (*Thesaurus Graecae Linguae*) by Ludwig Dindorf as follows, which I refer to bibliographically as Dindorf (1831: 1.2.1193): "Quod *ἀπαραυξῶν* [note the accent] scribendum erit si vera quae de *ἄναυξος* diximus in *Ἀναυξὴς*, quae legitima est horum compositorum ab *αὔξω* forma, ut *Ἐπαυξὴς* etc. *Ἀπηυξημένων* autem, quod vertitur Diminutorum, scribendum *ἐπηυξημένων*, si haec contraria praecedentibus." Dindorf would thus rewrite the passage as *ἤτοι τελέων τε καὶ ὡς αὐτοὶ καλοῦσιν ἀπαραυξῶν, ἢ καὶ ἐπηυξημένων κτλ*. (My understanding of why Dindorf thinks that the text, contrary to what went before, should read *ἐπηυξημένων* and the fractions thus increase, rather than decrease, is presumably to bring this phrase in line with Galen *de dignoscendis pulsibus* 3.3, 8.916: *οὐ δεομένοις τῶν πρώτων χρόνων ὁλοκλήρων τε καὶ παρηυξημένων*.)

While we await a critical edition of Galen's *de dignoscendis pulsibus* to improve on Kühn's text, von Staden (1989: xxiii) remarks that he has collated five manuscripts of the Galenic text but that in general they do not differ much from Kühn's text. He notes no changes from Kühn's text in his apparatus (1989: 347), thus giving the impression that the reading of *ἤτοι τελέων τε καὶ ὡς αὐτοὶ καλοῦσιν ἀπαραύξων, ἢ καὶ ἀπηυξημένων κτλ* is, *contra* Dindorf, the correct one. Correct Greek or not, what the passage precisely means remains something of a mystery.

Aristoxenian rhythmical theory through literary phenomena.

Herophilus' appropriation of Aristoxenian rhythmical theory is a strategy of naturalization, since Aristoxenus located his notion of the πρῶτος χρόνος in *physis*. Aristoxenus begins the second book of his *Elements of Rhythms* with a summary of the now lost first book:

> ὅτι μὲν τοῦ ῥυθμοῦ πλείους εἰσὶ φύσεις καὶ ποία τις αὐτῶν ἑκάστη καὶ διὰ τίνας αἰτίας τῆς αὐτῆς ἔτυχον προσηγορίας καὶ τί αὐτῶν ἑκάστῃ ὑπόκειται, ἐν τοῖς ἔμπροσθεν εἰρημένον … νοητέον δὲ δύο τινὰς φύσεις ταύτας, τήν τε τοῦ ῥυθμοῦ καὶ τὴν τοῦ ῥυθμιζομένου.
>
> That the *physeis* of rhythm are many, what each of these is, for what reasons they have the same name, and what can be predicated to each of them, has been said in the previous sections … Consider the following two *physeis*, that of the rhythm and that of the *rhythmizomenon*.[45]

As discussed above, Aristoxenus makes a division between rhythm and *rhythmizomenon*, the medium capable of assuming rhythm, and attributes a *physis* to both. Since the *protos chronos* is a descriptive category of *rhythmizomenon*, it follows that any object described in terms of the *protos chronos* is a *rhythmizomenon* and therefore part of *physis*. The pulsating artery is clearly an object capable of producing rhythm, a *rhythmizomenon.* Herophilus' description of the pulsating artery using Aristoxenus' *protos chronos* connects the *physis* of the timing of musical rhythm with the *physis* of the artery's movement in time, a naturalizing strategy of making connections between previously separate areas of *physis*.

Galen records an important testimonium about Herophilus' implementation of the primary time-unit to explain Herophilus' empirical identification of pulse rhythms, "a time-unit in relation to sense-perception".[46]

> γέγραπται μὲν οὖν καὶ Ἡροφίλῳ τὰ κατὰ τοὺς χρόνους μετὰ τῆς διαστολῆς τε καὶ συστολῆς, ἕνεκα τῶν ἡλικιῶν εἰς ῥυθμοὺς ἀνάγοντι τὸν λόγον. ὥσπερ γὰρ ἐκείνους οἱ μουσικοὶ κατά τινας ὡρισμένας χρόνων τάξεις συνιστῶσι παραβάλλοντες ἀλλήλαις ἄρσιν καὶ θέσιν, οὕτως καὶ Ἡρόφιλος ἀνάλογον μὲν ἄρσει τὴν διαστολὴν ὑποθέμενος, ἀνάλογον δὲ θέσει τὴν συστολὴν τῆς ἀρτηρίας, ἀρξάμενος ἀπὸ τοῦ νεογενοῦς παιδίου τὴν τηρησιν ἐποιήσατο, πρῶτον χρόνον αἰσθητὸν ὑποθέμενος ἐν ᾧ διαστελλομένην εὗρισκε τὴν ἀρτηρίαν, ἴσον δ' αὐτῇ καὶ τὸν τῆς συστολῆς εἶναι φησὶν, οὐ πάνυ τι

[45] Aristoxenus *Elementa Rhythmica* 2.1-3, 2.1-10 Pearson.
[46] Herophilus fr. 174.1-2 vS.

διοριζόμενος ὑπὲρ ἑκατέρας τῶν ἡσυχιῶν.

> So the time-units with dilation and contraction have been written also by Herophilus, since he drew ratio into rhythms for the sake of his age-groups. For just as musicians establish those <rhythms> in certain defined arrangements of time-units by comparing the up-beat and down-beat with each other, so Herophilus, supposing that the dilation of the artery was analogous to the up-beat and that the contraction of the artery was analogous to the down-beat, made his observation beginning from a newly born child. Supposing that a perceptible time-unit in which he found the artery dilating was primary, he claims that the <time-unit> of the contraction was at least equal to it, not quite distinguishing about either of the rests.[47]

Herophilus took a newborn to measure its pulse rhythm in dilation and contraction. He felt the dilation of an artery and called its temporal duration the primary time-unit. The time of dilation of the artery of the newborn thus becomes the common temporal measurement by which other sphygmological phenomena are measured. Galen next says that Herophilus claimed (φησὶν) that the length of time of arterial contraction is the same as the dilation.[48] Thus the time-unit of arterial dilation is equivalent to the time-unit of arterial contraction in a newborn. The ratio of dilation to contraction, that is, the rhythm of the infant's pulse, is thus a primary-time unit to a primary time-unit. The newborn child's pulse rhythm is thus 1:1. Later in Galen's testimonium Herophilus calls this pulse rhythm proportional (δι' ἴσου).[49]

Herophilus established a normative pulse rhythm not only for infants: each age-group has its own pulse rhythm. Probably the most significant passage for our understanding of Herophilus' pulse rhythms, a section of [Rufus of Ephesus]' *Synopsis of*

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[47] Galen *synopsis librorum suorum de pulsibus* 12, 9.463-5 K = Herophilus fr. 183.1-11 vS.

[48] The text is loose with language here. In ἴσον δ' αὐτῇ καὶ τὸν τῆς συστολῆς εἶναι φησὶν equivalence is between the time-unit of contraction (τὸν τῆς συστολῆς) and dilation itself (αὐτῇ), when it needs to be between the time-unit of contraction and the *time-unit* of dilation, which would be τῷ αὐτῆς in Greek. Yet it is clear that the equivalence between time-units is what is meant, since in the third paragraph (Herophilus fr. 183.22 vS) Galen says that the rhythm of the pulse in newborns is equal (δι' ἴσου). Moreover, since Galen does not believe that arterial contraction is easily perceptible (see Appendix A), perhaps Galen is asserting his own views of what was possible for Herophilus or perhaps Herophilus did, as Galen says, assume and not measure that the time of arterial contraction was equivalent to arterial dilation. It is clear at least that Herophilus did equate dilation with contraction.

[49] Herophilus fr. 183.22 vS. The terminology of rhythmical proportionality is mathematical. See ἴσος 3.b in Mugler (1958: 229-231).

Pulses, reveals how Herophilus qualified pulse rhythm for all other age-groups. [Rufus] has just explained how Herophilus' pulse for infants was equivalent in ratio, 1:1.

> προβαινούσης δὲ τῆς ἡλικίας καὶ τοῦ σώματος εἰς αὔξησιν ἐρχομένου, καὶ ὁ σφυγμὸς πρὸς λόγον μεγεθύνεται, πρὸς λόγον τὴν διαστολὴν τῆς συστολῆς λαμβάνων πλατυτέραν· ὅ τε λοιπὸν ἔστιν αὐτοῖς καὶ ἐφαρμόσαι πρὸς ἀπόδειξιν ἐκ τοῦ ποδισμοῦ τῆς γραμματικῆς· ὁ μὲν γὰρ πρῶτος ἐπὶ τῶν ἀρτιγενῶν παίδων εὑρισκόμενος σφυγμὸς ῥυθμὸν λήψεται τὸν τοῦ βραχυσυλλάβου· καὶ γὰρ ἐν τῇ διαστολῇ καὶ τῇ συστολῇ βραχὺς ὑπάρχει, καὶ διὰ τοῦτο δίχρονος νοεῖται· ὁ δὲ τῶν πρὸς αὔξησιν ὄντων ἀναλογεῖ τῷ τε παρὰ ἐκείνοις ποδὶ τροχαίῳ· ἔστι δὲ οὗτος τρίχρονος, τὴν μὲν διαστολὴν ἐπὶ δύο χρόνους λαμβάνων, ἐπὶ ἕνα δὲ τὴν συστολήν. ὁ δὲ τῶν ἀκμαζόντων ταῖς ἡλικίαις ἐν ἀμφοτέροις ἴσος ὑπάρχει, ἔν τε τῇ διαστολῇ καὶ τῇ συστολῇ, συγκρινόμενος τῷ καλουμένῳ σπονδείῳ, ὃς τῶν δισυλλάβων ποδῶν μακρότατός ἐστιν· ἔστιν οὖν συγκείμενος ἐκ χρόνων τεσσάρων. τοῦτον τὸν σφυγμὸν Ἡρόφιλος διὰ ἴσου καλεῖ. ὁ δὲ τῶν παρακμαζόντων καὶ σχεδὸν ἤδη γερόντων καὶ αὐτὸς ἐκ τριῶν σύγκειται χρόνων, τὴν συστολὴν τῆς διαστολῆς διπλῆν παραλαμβάνων καὶ χρονιωτέραν.
>
> As the age-group advances and the body grows, the pulse too enlarges in ratio, taking in ratio a broader dilation than contraction. As for the rest, it is possible for them to harmonize as regards the proof from the scansion of grammar. For the pulse found first in recently born children will take for its rhythm that of a short syllable: for it is short in dilation and contraction and for this reason is considered two time-units. The <pulse> of those growing is analogous to the foot [called] by them trochee. This is three time-units, taking its dilation for two time-units and its contraction for one <time-unit>. The <pulse> of those prime in their age-group is equal in both, in both dilation and contraction, and is comparable to the so-called spondee, which is the longest of the disyllabic feet. This is composed of four time-units. Herophilus calls this pulse proportional. The pulse of those past their prime and nearly old people already is itself composed of three time-units, offering a contraction twice its dilation and longer.[50]

Children, as we have just seen, have a pulse rhythm two primary time-units long, one for dilation and one for contraction. When set in ratio, as per musical rhythm, this pulse is a 1:1 ratio or, in musical terms, a primary time-unit to a primary time-unit and thus a metrical pyrrhic. Youths have a pulse three time-units in length, two for dilation and one for contraction; this pulse is a 2:1 ratio or a diseme to a primary time-unit and thus a metrical trochee. Adults have a pulse four time units long, two for dilation and two for contraction; this pulse is a 2:2 ratio or a diseme to a diseme and thus a metrical spondee. Old people have a pulse three time-units in length, one for dilation and two for

[50] [Rufus of Ephesus] *Synopsis de pulsibus* 4, 223-5 Daremberg/Ruelle = Herophilus fr. 177.12-30 vS.

contraction; this pulse is a 1:2 ratio or a primary time-unit to a diseme and thus a metrical iamb.

This passage shows Herophilus establishing normative rhythms for each age-group. Although the term 'primary time-unit' does not appear in this passage, Herophilus employed some similar notion, for the passage talks in terms of χρόνοι or time-units. What is the basis of the *protos chronos* which forms these time-units? Herophilus employed the time of dilation of the artery of the newborn as the time-unit *protos chronos* for all age-groups, for [Rufus of Ephesus] indicates that there is some comparison across age-groups: if there is no descriptive *mensurandum* common to all age-groups, it is difficult to see how Herophilus intended to compare pulse rhythms.[51]

Herophilus' solution in turn leads to two possibilities, both problematic. (1) The first possibility is that Herophilus described the rhythm of the infant's dilation to contraction as 1:1 generically, i.e. that any member of the infantile age-group has a 1:1 pulse rhythm with a generic *protos chronos*. This would imply that the *protos chronos* Herophilus identifies is generic and typologized to some degree: the infant's *protos chronos* is the fixed time Herophilus identified by perception; this time of the *protos chronos* is taken to stand for the *protos chronos* of all other infants, and further that this *protos chronos* is the basis of the temporal measurements of the rhythms of all other age-groups. This procedure allows Herophilus to compare pulse rhythms across age-groups, as [Rufus of Ephesus] indicated. But in so doing Herophilus has moved the *protos chronos* closer to a set time and thus negated much of the flexibility of the measurement of the *protos chronos*, which can vary with each individual. (2) The second possibility of interpretating the infant's 1:1 pulse is that Herophilus identified a unique *protos chronos* with each individual patient and that, as the individual grows into new age-groups, the

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[51] [Rufus of Ephesus] *Synopsis de pulsibus* 4, 223-5 Daremberg/Ruelle = Herophilus fr. 177.12-30 vS seems to indicate that there is a comparison of time-units across age-groups: the short syllables of the infant's pyrrhic pulse rhythm are comparable to the short syllables of the teenager's trochaic pulse rhythm. Galen's *de dignoscendis pulsibus* 3.3, 8.913K = Herophilus fr. 174.1-10 vS claims that Herophilus establishs "some time-unit in relation to sense-perception, by which he, in measuring the other <time-periods>, claimed that they consist either of two or three or more [of these units]".

patient's 2:2 rhythm of adulthood is measured on the basis of his childhood *protos chronos*.[52] While conforming better to Aristoxenus' sense of the flexibility of the temporal measurement of the *protos chronos* and allowing a comparison of pulse rhythms across age-groups per individual, this possibility seems to destroy the clinical efficacy of the measurement of pulse rhythm, since a doctor without knowledge of an individual patient's childhood *protos chronos* is unable to use the pulse rhythm for diagnosis and prognosis.

And yet it is clear at least that there is a correspondence of diction and situational context between Aristoxenus' theory of the *protos chronos* and Herophilus' fragments on pulse rhythm, and further that Herophilus has developed a basic unit of measurement in accord with Aristoxenus' procedure for identifying the *protos chronos* as the smallest temporal unit of the *rhythmizomenon*'s motion apparent to perception. That is, Herophilus has appropriated Aristoxenus' language and development of the *protos chronos*, but Herophilus' use of the theoretical concept seems to negate the flexibility of the *protos chronos*. If we interpret Herophilus' identification of the infant's *protos chronos* in sense (2) above, the more our intepretation will assert Herophilus' appropriation of Aristoxenus in all respects of Aristoxenus' theory and yet Herophilus' pulse theory will be less medically coherent and useful for diagnosis and prognosis. If we interpret Herophilus' identification of the infant's *protos chronos* in sense (1) above, the more our interpretation will lessen the effectiveness of Herophilus' appropriation of Aristoxenus' *protos chronos* and yet will give medical purpose to Herophilus' comparison of pulse rhythms. I prefer to give an interpretation which assumes the medical purposiveness of Herophilus' theory at the expense of his appropriation of Aristoxenus in all respects.

Therefore, I argue that we should understand the infant's 1:1 pulse according to interpretation (1) above. The infant's pulse is a typologizeed and generic measurement, which serves as the basis for the temporal phenomena of the pulse rhythms of other age-

[52] We assume that each individual patient has his own pulse rhythm, which can be measured according to a unique *protos chronos* derived from observation of that individual.

groups. When we compare the infantile age-group's 1:1 pulse rhythm to the adult age-group's 2:2 rhythm, they have the same ratio of dilation to contraction but different rhythms; and further, since the infantile *protos chronos* is the temporal measurement common to age-groups, the infant's cycle of dilation to contraction moves twice as quickly as an adult's 2:2 pulse rhythm. That is, the *protos chronos* of the infant is a normative time for the infantile age-groups, but a standardized time for the adult age-group. Thus what becomes important in this schema is the patient's classification into age-groups, not the individual patient's uniquely determined *protos chronos*. I argue in 2.4.2 that Herophilus' therapeutic use of pulse rhythm depends on the patient's classification within a typologized schema of rhythms per age-group.

Therefore, the time of dilation of the infant's pulse thus becomes the common unit of temporal measurement by which the pulse rhythms of other age-groups are measured. By setting the infant's *protos chronos* as the norming standard of other age-groups, Herophilus is able to measure the duration of the pulse of other age-groups. Like Aristoxenus' *protos chronos*, Herophilus' *protos chronos* establishes a normative time measurement, that is, measuring an event by the duration of the primary time-unit. Moreover, just as in Aristoxenus' example of a spoken sentence, Herophilus' *protos chronos* remains constant for its *rhythmizomenon* while the length of standard time varies. [Rufus of Ephesus] explains that the infant's pulse is 1:1, a primary time-unit to a primary time-unit and that the adult's pulse is 2:2, two primary time-units to two primary time-units. The infant and the adult beat out their individual pulse rhythms using the normative measurement of the *protos chronos* in two different standardized times. The rhythm of dilation to contraction remains the same within age-groups while the rhythm of dilation to contraction changes between age-groups.

In summary, Herophilus employs a *protos chronos*, the primary time-unit, to serve as the standard *mensurandum* of pulse phenomena. He identifies this *mensurandum* with his own ability to determine the time of the dilation of the infant's artery. Herophilus' adaption of Aristoxenus' *protos chronos* to measure pulse phenomena consequently utilizes the descriptive attributes of *physis* in one field, music,

and applies that description to another aspect of *physis*, the expansion of the infant's dilating artery. As the summary of Lloyd's (1991b) argument showed in 2.1.1, Hellenistic period scientists' appeal to *physis* is an appeal to a unified conception of nature whose attributes under one science might be recognized in another science. The naturalization of Herophilus' strategy of *interessement* in adapting Aristoxenian *protos chronos* is therefore an implicit recognition of the unity of *physis* across scientific domains. The naturalizing link is made at one point: Herophilus' identification of the time of the infant's dilating artery with Aristoxenus' *protos chronos*.

2.2.2 Herophilus' Water-Clock

Herophilus' other attempt to measure the timing of pulse phenomena is by means of a water-clock. The one account of Herophilus' application of a water-clock to pulse measurement comes from Marcellinus' *On Pulses*, a short second-century CE treatise concerned with enumerating differences in the pulse theory of prominent ancient doctors.[53] Marcellinus' description of Herophilus' practice is exciting for several reasons: (1) it shows Herophilus' concern for practice as well as theory;[54] (2) it shows that some ancient scientists were able to integrate machines into their study of nature, yielding Latour's technoscience;[55] (3) it shows that some ancient Greek scientists had an interest in quantification to the extent of mathematizing nature.[56] I will argue that

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[53] While I believe that Marcellinus' report about Herophilus' water-clock is historically accurate, I stress two notes of caution. First, Marcellinus' is the only report that Herophilus used a water-clock; no other source indicates that any ancient doctor applied timing devices to measure pulse frequency. Second, Marcellinus post-dates Herophilus by 400 years and it is striking that so interesting a scientific attempt went unrecorded in other extant medical sources interested in either mechanical devices or pulse theory, such as Galen and Oribasius. Despite these caveats, the fact that Herophilus' water-clock is an Egyptian style of water-clock is a strong argument that Marcellinus' report is historically accurate for Herophilus' context in early Alexandria.

[54] Von Staden (1989: 283): Marcellinus' report "strikingly demonstrates Herophilus' desire to bridge the gap between theory and practice."

[55] See chapter 1.4 for this concept.

[56] See Lloyd (1987: 283-4): "[T]here is the evident *ambition* to make the inquiry an exact one, to construct pulse theory on the model of music, the successful mathematisation of harmonics. If the main concords are expressible in terms of simple numerical relationships, why not also the main ratios between dilations and contractions of the arteries?" Lloyd confuses what sort of 'music' the ancient sources refer to; in reference to Herophilus' theories of pulse rhythm, it is rhythmical theory not harmonic theory.

Herophilus' application of the water-clock to measure pulses is a Greek use of normativized time on an Egyptian style of water-clock.[57]

Marcellinus offers first the position (*στάσις*) of Herophilus on the pulse of those with fever and then concludes his description of Herophilus' theoretical view with an account of his practice.

> *οὕτω δὲ τῇ πυκνοσφυξίᾳ τὸν Ἡρόφιλον θαρρεῖν λόγος ὡς βεβαίῳ σημείῳ χρώμενον, ὥστε κλεψύδραν κατασκευάσαι χωρητικὴν ἀριθμοῦ ῥητοῦ τῶν κατὰ φύσιν σφυγμῶν ἑκάστης ἡλικίας εἰσιόντα τε πρὸς τὸν ἄρρωστον καὶ τιθέντα τὴν κλεψύδραν ἅπτεσθαι τοῦ πυρέσσοντος· ὅσῳ δ' ἂν πλείονες παρέλθοιεν κινήσεις τῶν σφυγμῶν παρὰ τὸ κατὰ φύσιν εἰς τὴν ἐκπλήρωσιν τῆς κλεψύδρας, τοσούτῳ καὶ τὸν σφυγμὸν πυκνότερον ἀποφαίνειν, τουτέστι πυρέσσειν ἢ μᾶλλον ἢ ἧττον.*
>
> The story goes that Herophilus was so encouraged in using the frequency of pulse as a secure sign that he constructed a water-clock holding an expressed measurement for the natural pulses of each age-group and that on entering in to the patient and setting down the water-clock felt the patient with fever <for his pulse>. By as much as the greater movements of pulses overshot the <magnitude> natural for the filling-out of the water-clock, by so much did he reveal the pulse to be more frequent, that is, either more or less feverish.[58]

Marcellinus recounts that Herophilus constructed a water-clock to quantify the extent of a patient's fever; the clock contained measurements, likely lines drawn inside the bowl, set for each age-group. Frequency, the *differentia* measured by Herophilus' water-clock, is different from the *differentia* of rhythm measured by Aristoxenus' *protos chronos*.[59] The

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[57] Since Herophilus was a Greek colonist to Egypt, colonialism is a potentially important framework for understanding Herophilus' theory of pulsation. Ancient Egyptian doctors also employ pulse in their medicine. Dynastic Egyptian doctors refer to the pulse in the Ebers Papyrus and the Smith Papyrus; see Barton (1994b: 152) for further bibliography. Von Staden (1989: 9-13) cautions that the structural comparison of Greek and Egyptian vascular systems does not result in the same diagnostic use of the pulse for the medicine of each culture. My analysis focuses on Herophilus' use of native Egyptian technology.

[58] Marcellinus *de pulsibus* 11, 463 Schöne = Herophilus fr. 182.8-15 vS.

[59] What *differentia* does 'frequency' correspond to in Herophilus' thought? 'Frequency' as a *differentia* occurs only in Marcellinus' report of Herophilus' water-clock and discussion of Herophilus' prognosis of patients with fever, discussed in 2.4.1. Von Staden (1989: 284) discusses how later Greek physicians employed 'speed' and 'frequency' as distinct *differentiae*. He concludes that, whatever the relationship between 'speed' and 'frequency' in Herophilus' thought, Herophilus "did not merely develop 'speed' as a hypothetical differentia which in practice was abandoned in favour of 'frequency,'" as Herophilus' specific classifications of 'speed' show. While it is possible that Herophilus intended 'frequency' to correspond to 'amount' (the fifth *differentia* listed at the beginning of his treatise *On Pulses*) due to 'amounts' of water at the measurement lines appropriate for the different age-groups in Marcellinus' report of Herophilus' water-

timing device of a water-clock is not the frequency of the individual drops but rather their collective accumulation in a bowl or vessel underneath. When the vessel underneath is filled, a set period of time has elapsed;[60] the doctor will subsequently compare the number of beats he has counted to the number he would expect in the patient's age-group, the frequency of pulse beat.

The water-clock and sundial were the only time measuring devices available in Greco-Roman antiquity; the water-clock was by far the more precise.[61] All water-clocks operate by allowing gravity to force falling water from one vessel to another. They differ in the amount of water they hold, the rate of the falling water, and whether the falling water is measured in the upper or lower vessel. There are three kinds of water-clocks but only two are relevant for Marcellinus' report about Herophilus: these types are out-flow clocks and in-flow clocks.[62]

In an out-flow clock gravity forces water to flow from a vessel with a small exit hole. The clock's timing is measured by the amount of water that flows out from the vessel. An out-flow clock needs only one vessel, since the water could flow out onto the ground, although to reuse water a lower catching vessel was often employed. It seems that the Greek term κλεψύδρα, translated as 'water-clock',[63] refers only to the vessel by which time was measured: in the case of the out-flow clock κλεψύδρα refers to the upper vessel (if there was a second, lower catching vessel). The out-flow clock was known in both ancient Greece and dynastic Egypt. A water-clock from the Athenian agora, shown in illustration 1, is the only extant pre-Hellenistic Greek out-flow water-clock recovered.

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clock, the matter is still not clear to me. I treat 'frequency' as a separate *differentia* original to Herophilus but unenunciated in the catalogue of *differentiae* in *On Pulses*.

[60] The modern analogue is the kitchen timer: its buzz at the elapsed time records a length of time rather than individual moments, as a stop-watch does.

[61] For scholarship on water-clocks in antiquity see Borchardt (1920) for Egyptian clock capabilities, Pogo (1936) for Egyptian material remains, Young (1939) for Athenian material remains, Drachmann (1948) for Greek theoretical treatises and typologies, and Landels (1979) for theoretical and practical issues involved in the production of water-clocks.

[62] See Borchardt (1920: 6) for out-flow and in-flow clocks; see Drachmann (1948: 16-18) for a constant-flow clock. Drachmann's (1948) third kind is not portable and Marcellinus *de pulsibus* 11 says that Herophilus carried his with him: εἰσιόντα τε πρὸς τὸν ἄρρωστον καὶ τιθέντα τὴν κλεψύδραν "entering in to the patient and setting down the water-clock."

[63] LSJ *s.v.* II.

Holding 6.4 litres, it empties in six minutes; it has no markings on the interior of the vessel.

Illustration 1: Athenian Water-Clock.[64]

The oldest extant dynastic Egyptian out-flow water-clock dates from c.1380 BCE and holds 39 liters of water, roughly six times larger than the extant Athenian clock.[65] As an astronomical device, the outside of the Egyptian clock is covered in hieroglyphs for the twelve months of the calendar. As shown in illustration 2, the inside of the clock is covered by twelve series of vertical markings: set at varying heights, they mark the differing length of hours that have passed of the night for any given month. As the water-flows out, an observer can mark the passing of an hour at different times of the year by inspecting the interior of the out-flowing vessel.

We can distinguish between how the clock functions and the use to which it is put. The Greek water-clock was used for what I will call normative time, that is, measuring an event by the duration of the clock's emptying. Greek water-clocks, like the clock from the agora, were used to limit the length of the speaker's time in court cases such that different types of legal cases had different time lengths established for the prosecution and defense. Thus the duration of the clock establishes the norm against

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[64] Young (1939: 284).

[65] For an assessment of the Egyptian clock's capabilities, see Borchardt (1920: 14-19). For the best illustration of the clock's exterior see Neugebauer and Parker (1969: plate 2); for the illustration of the clock's interior see Borchardt (1920: plate 3).

which the event is measured. Without markings on the inside of the clock it is impossible to measure fractions or parts of the time which elapses as the water in the clock flows out.

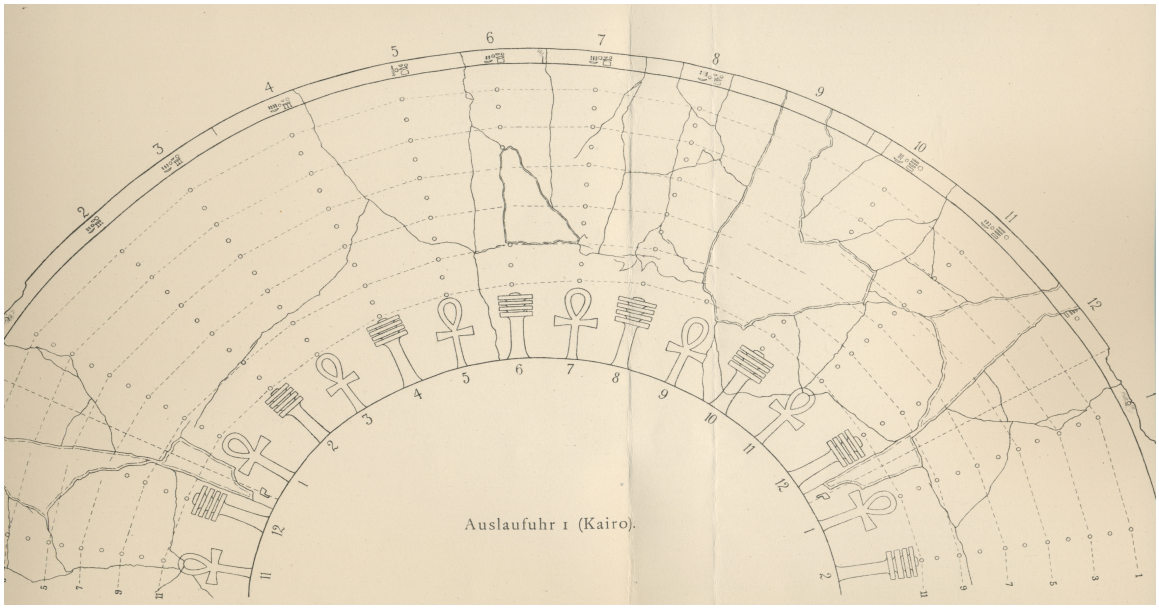

Illustration 2: Interior of Egyptian Water-Clock.[66]

The Egyptian clock, by contrast, is used for what I will call standardized time, that is, measuring segments of passing time. The Egyptian clock measures the hours of the passing night for each month, as a way for the astronomer to regulate his own position in the night. Thus the water-clock regulating standardized time measures itself against the visual position of the sun, moon, and stars around the earth. The internal markings of the bowl allow the clock's user to measure standardized fractions of passing time.

The second type of water-clock is an inflow clock, known only from dynastic Egypt. (The inflow clock was not known in classical Greece; the earliest archaeological evidence for an in-flow clock in Greece dates from the Roman period.[67]) In the in-flow clock gravity forces water flowing from an upper container into the receiving chamber; the timing device is the amount of water filling-in to the receiving chamber. An in-flow clock thus needs two vessels; its measuring bowl, the lower vessel, is called κλεψύδρα in

[66] Borchardt (1920: plate 3).
[67] See *The Athenian Agora: A Guide* (1976: 168-69) with reference to the Tower of the Winds.

Greek. Many small Egyptian in-flow clocks survive; some only nine centimeters high, they are votive offerings intended to represent larger in-flow clocks but are not marked inside their receiving bowls. Illustration 3 shows a Ptolemaic king, dressed as an Egyptian pharaoh, offering to a goddess a votive in-flow water-clock in his outstretched left hand. The one large surviving in-flow water-clock from dynastic Egypt, an astronomical device, is marked inside its receiving bowl.[68] Due to the interior markings of the receiving chamber, the Egyptian in-flow clocks, like Egyptian outflow clocks, measure standardized time.

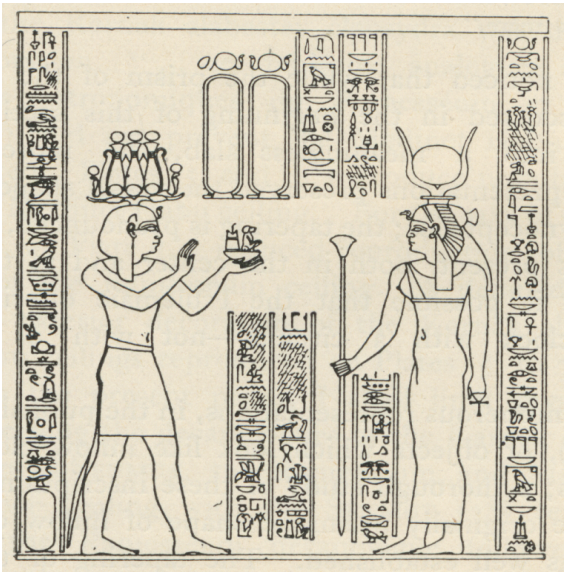

Illustration 3: Ptolemaic Pharaoh Offering a Votive Water-Clock.[69]

Now Herophilus' water-clock is a normative use of time, as in the Greek style of clock. Marcellinus recounts that Herophilus constructed a water-clock to quantify the extent of a patient's fever for each age-group. The measurement bowl of Herophilus' water-clock thus provides a segment of standardized time during which a normative number of pulse beats is expected. Thus Herophilus' use of the water-clock is a

[68] Borchardt (1920: plate 6) illustrates both the exterior and interior of the surviving dynastic Egyptian large in-flow water-clock.
[69] Pogo (1936: 421-22), who believes that the pharaoh is the Ptolemaic king Ptolemy XII Auletes.

normative use of the clock, measuring the pulse against the standardized period of time of the clock.

Herophilus' water-clock is also an in-flow water-clock, as in the Egyptian style of clock. First, Marcellinus' noun ἐκπλήρωσιν, meaning "filling up",[70] confirms that Herophilus has used an in-flow clock. The action of the water *filling up* the measuring vessel only takes places in the inflow clock.[71] Second, Marcellinus' phrase χωρητικὴν ἀριθμοῦ ῥητοῦ implies that Herophilus has made a receiving bowl capable of measuring the amount of water that should flow in for a specified number of beats for each of the different ages. The noun χωρητικὴν literally means "capable of having space", i.e. a capacity for holding or containing, as in the capacity of the bowl of the clock.[72] P.Oxy. 470, an Oxychrynchus papyrus describing how to build a water-clock, employs terminology similar to Marcellinus' description of Herophilus' water-clock.[73] The papyrus clock appears to be an out-flow clock on the conic frustrum model of the dynastic Egyptian clock. In particular, the papyrus describes the dimensions of the clock as follows:

> τὸν δὲ τῶ[ν ὡ-|ρολογίων ἀριθμὸν τῆς [κα-|τασκευῆς οὕτως ἀ[πο-|διδόασιν, τὸ μὲν ἄνω [|ὁλμίσκου δακτύλων [κδ |ποιοῦντες, τὸν δὲ πυθμέν[α |ιβ δακτυλων, τὸ βάθος δ[α-|κτύλων ιη.
>
> They transmit the measurement of the build of the timing-devices as follows, making the upper conic section twenty-four dactyls, the base twelve dactyls, and the depth fifteen dactyls.[74]

The papyrus seems to use ἀριθμὸν, literally "number", to indicate the dimensions and capacities of the measuring bowl. Applying this sense of ἀριθμὸν to the Marcellinus passage, ἀριθμοῦ ῥητοῦ in Marcellinus will refer to the dimension of the clock. Together

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[70] LSJ *s.v.* I.

[71] Von Staden's (1989: 354) apparatus records Schmidt's conjecture of ἐκκένωσιν for ἐκπλήρωσιν. Schmidt thus understood Herophilus' water-clock to be an out-flow clock. Von Staden's text should be retained.

[72] LSJ *s.v.* χωρητικός 1.

[73] See Grenfell and Hunt (1903: 141-46) for an edition of the whole and commentary on particular passages. See also Borchardt's (1920: plates 7-8) edition of the text, which has emendations to bring the papyrus clock's dimensions into harmony with the known material remains.

[74] P.Oxy. 470.31-38.

χωρητικὴν ἀριθμοῦ ῥητοῦ will therefore refer to the measurement bowl of the clock, "holding an expressed measurement". Finally, the verb in the Marcellinus passage, παρέλθοιεν, meaning "overshoot", indicates that the measurement bowl will have been marked inside with a level appropriate for each age-group. Suppose then that a line inside the measure bowl appropriate for the age-group of adults corresponds to 50 beats: if the doctor feels 60 beats in the time period of the bowl's filling to the measurement line, the patient's pulse overshoots the norm for the age-group.

We thus imagine Herophilus entering the house of the patient, setting down an apparatus which allows water to flow into an in-flow water-clock at a predictable rate, holding his patient's forearm to feel the pulse, and counting pulse beats as the water fills the bowl to the measuring lines appropriate for the patient's age-group. Herophilus' attempt to quantify the pulse by water-clock is a new concept: the application of an standardized measurement to normal pulse frequency. The water-clock was an old and traditional tool in both Greek and Egyptian culture, of which the in-flow clock with interior marking seems to have ben favored in Eygpt, the out-flow clock in Greece. Egyptian clocks were used for standardized time, Greek clocks were used for normative time. I therefore suggest that we see Herophilus the Greek colonist using an Egyptian tool for a Greek conceptual end.

Finally, let us conclude by returning to the comparison by intertexuality$_R$ of Herophilus' multiple attempts to measure the pulse with some temporal concept. Herophilus' water-clock's normative use of time parallels Herophilus' use of Aristoxenus' theory of musical rhythm. Aristoxenus' theory of musical rhythm adapts its temporal measurement to the smallest divisible element of the *mensurandum*. Herophilus identified the infant's dilation as the smallest divisible element of arterial pulsation; he constructed the artery's temporal rhythm by using multiples of the temporal unit by which he measured the infant's dilation. Since Herophilus' measurement of the pulse by the *protos chronos* is the measurement of a temporal event against an elapsed time, the notion of the primary time-unit is thus also a normative measurement of time, as was argued in 2.2.1. In both his adaption of Aristoxenus' *protos chronos* and utilization of the in-flow water-clock Herophilus employed foremost Greek conceptual understandings

of time. If historians cannot judge the chronological priority of Herophilus' multiple attempts to measure the timing of the pulse and its constituent parts, we can at least emphasize the conceptual continuity between these two attempts.

2.3 Emergence, or Novelty Embedded

Herophilus' new object, pulse, thus results from multiple elements. I will call Herophilus' pulse a materio-semantic object in order to emphasize different layers of its process of coming-into-being. The new object arose from empirical phenomena such as Herophilus' identification of arterial dilation, the length of time of arterial expansion, and the time of filling-in of Egyptian-style in-flow water-clocks. The new object also arose from conceptual categories: Aristoxenus' primary time-unit, the assumption of equivalence between arterial dilation and contraction in the infant's pulse, the Greek mathematics of proportionality and ratio, the Greek notion of normative time, Herophilus' own mental ability to identify arterial expansion, and so on. The pulse therefore has both a material component, the length of time of arterial expansion, and semantic ones, derived variously from language, tradition, practical skill, and the cultural identification of time. The discovery of a new scientific object does not come without this compound of empirical and mental categories, without phenomena that are ahistorical and phenomena unique to a given time and place. Herophilus did claim that only arteries pulsate; that is true. Herophilus described those pulsations in a way that depended on contemporary musical terminology; that is a historical science.

The philosophical theme of Herophilus' pulse theory is therefore the emergence of new concepts and ideas in science. We might variously call Herophilus' pulse theory a discovery or invention and thereby signal our philosophical commitment to realism or relativism, respectively: if we say that Herophilus discovered the pulse, we mean that the pulse is a biological reality, a permanent and enduring object whose existence does not depend on human perception and is hence subject to the cultural qualifications of human perception; conversely if we say that Herophilus invented the pulse, we mean strongly that Herophilus' concept – whatever it was – was not only not our concept of pulse but indeed so solely dependent on the cultural conditions of human perception that it exists

outside of the natural realm and only inside the cultural conditions of Herophilus' Greek culture in early Alexandria. But I want to resist framing the debate about Herophilus' pulse theory in the abused dichotomy of realism and relativism.

Barton (1994b) and Kuriyama (1999) have each made the strong claim that the pulse is not biologically given but is a cultural construct.[75] In their explanation, pulse is not a natural phenomenon but is socially constructed within a tradition of cultural discourse, which serves both to create and reify concepts significant for a social group. Herophilus' pulse rhythm is of course a cultural construct that is subject to genealogical scholarship: the notion of pulse came into being, the boundaries of the object were contoured by means of textual and ostensive definitions, the object assumed an importance for certain social groups. The semantic parameters within which Herophilus developed pulse rhythm are these cultural constructs of language usage and social need.

Yet it would be a mistake to assert baldly that Herophilus' pulse rhythm lacks any biological content at all: there is some biological phenomenon to which Herophilus refers his notional claims, namely the duration of arterial dilation.[76] Somatic material is not a

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[75] See Kuriyama's (1999: 17-108) comparison of Greek and Chinese accounts of the pulse. Barton (1994b: 162-3) summarizes Kuriyama's (1987) dissertation, the basis of his (1999) book: "It is also illuminating to set beside Greek pulse lore in general the Chinese art of *qie mo*, as Kuriyama (1987) has done. The ethnocentric value judgments made on this art by Western physicians and historians of science resulted from fundamental misapprehension: they assumed that the two could be seen as variant forms of pulse diagnosis, as different interpretations of a common reality. But, as Kuriyama argues, there is no common reality: the pulse is not given in nature, common to all cultures, but is, instead, a cultural artifact, forged in historical circumstances. The *mo* to which Chinese physicians sensitized themselves required techniques and beliefs incompatible with the Greek vision of the pulsating artery. And the two presuppose different conceptions of how words relate to the experiences of the touch. While the Greeks relied on the capacity of the mind to conceive images, *qi*, 'like minds,' could not be seen. Instead its movements had to be apprehended by the reponse of an uncluttered mind; its directions of flow had to be sensed. Obviously, there is more than just another model of the body involved here." In the previous paragraph Barton (1994b: 162) argued that any attempts to understand ancient Greco-Roman pulse theory as "an extremely complex empirical differentation of pulses" was doomed to failure "within the paradigm of the modern scientific method." Barton's (1994b: 1-25) introduction avowedly embraces a relativist point of view against realism.

[76] Biological phenomena seem especially available to sense perception. Kuriyama's (1999) book excellently explains the different skills of touching, developed from different cultural contexts, of Greek and Chinese physicians: he argues that Greek and Chinese physicians are not even feeling the same physical phenomena because the 'physical' objects to which they referred their touch were different. Kuriyama (1999: 35) encourages his readers to test their ability to feel their own pulse and attempt to sense the cycle of arterial dilation and contraction. I encourage my readers to do likewise. In the interest of

blank canvas on which culture is drawn; rather, as ANT argues, natural material symmetrically interacts with social phenomena to produce stable scientific objects, both naturally and socially constituted. Since Herophilus' pulse rhythms lasted as a feature of Greek traditions of medicine well into the 18th century in Western Europe thus producing a complex reaction between cultural perceptions of rhythm and the biological epiphenomena of arterial dilation and contraction, Herophilus' pulse rhythm would seem to constitute as salient or permanent a scientific object as premodern science would allow.[77] Barton's (1994b) and Kuriyama's (1999) accounts are incomplete, at least as they apply to Herophilus. It will not suffice to treat Herophilus' interest in naturalization – that is, naturalization construed as both natural phenomena and cultural givens – only as a rhetorical exercise of personal advancement in the face of social polemic, Barton's (1994b) thesis. Herophilus' pulse rhythm is a materio-semantic object with complex roots in both cultural traditions of knowledge and empirical perceptions.[78]

Reading Herophilus' pulse theory by ANT emphasizes not only its materio-semantic traits but also the actant allies which Herophilus has enrolled in his assemblage. Above in chapter 2.1.1 I discussed Herophilus' potential strategies of *interessement* of both social and natural phenomena. We have seen Herophilus integrate many natural phenomena into his account of the pulse. From anatomy Herophilus intertwined the

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academic honesty, I confess I can feel my carotid artery striking my finger but can make no distinction between dilation and contraction nor can I even sense arterial dilation. If this suggests that I am a poor pulse-taker, it also suggests that a high degree of practical skill is needed to make concepts refer consistently to biological epiphenomena. For a corresponding scenario and conclusion see Hacking's (1988) account of the positive philosophical consequences of Bruno Latour's poor laboratory skills.

[77] For later European traditions of rhythm in pulse theory see Kümmell (1977), which is illustrated with several Renaissance charts writing pulse rhythm on Western musical staffs.

[78] Further research on this topic to connect Greek visions of the pulsing artery with the vivisection of Herophilus and Erasistratus might proceed with von Staden (1993) in mind. In a thought-provoking article seemingly little noticed, von Staden (1993: 55-6) has advocated a focus on semantics of matter for the ancient historian of science: "The chaste tree illustrates the rich repository of cultural signification represented by the 'natural matter' used, for example, in Greek science and in Greek cults. Attention to the meanings of such matter-in-use not only is a curb on decontextualizing readings of texts, it also spurs on reconsideration of the very nature of ancient 'science' as a theoretical and pragmatic activity that, while not a mere epiphenomenon of political, legal, or religious culture, yet is inextricably embedded both in the verbal and in the 'material' culture of its times. The brilliant, often transformative methodological, epistemological, rhetorical, and pragmatic innovations of ancient science, on which much modern historiography has dwelt, must be accommodated in any responsible reading of ancient cultures."

natural givens of the anatomical movement of arteries in dilation and contraction through the *differentiae* of arterial size, speed, and vehemence. Herophilus linked temporal phenomena with the pulse by two different means: first, Herophilus' appropriation of Aristoxenus' concept of the primary-time unit in musical rhythm linked a natural given of musical rhythm; second, Herophilus' measurement of the frequency of the pulse by water-clock utilized the filling of a culturally specific Egyptian in-flow water-clock. It is worth underscoring how 'real' an object Herophilus has assembled. His theory of pulse is supported naturally by physical and temporal phenomena: the culturally accepted existence of the pulse was well established.[79] Herophilus' pulse theory therefore gains its scientific objectiveness from its embeddedness inside preexisting networks of natural and cultural phenomena.

2.4 Prognosis, Therapy, and Ideology of Herophilus' Pulse Theory

2.4.1 Prognosis

Galen states that Herophilus sought a way to utilize pulse for prognosis of diseases.[80] We therefore expect Herophilus to have written on diseased patients and their types of pulse or, perhaps vice versa, on types of pulse as indicators of disease. Apart from Galen's testimony, we have only one testimonium from Marcellinus for Herophilus' interest in prognosis using the pulse.

> ὁ δὲ Ἡρόφιλος πυρέσσειν ἀπεφήνατο τὸν ἄνθρωπον, ὁπόταν πυκνότερος καὶ μείζων καὶ σφοδρότερος ὁ σφυγμὸς γένηται μετὰ πολλῆς θερμασίας ἔνδον. εἰ μὲν οὖν προαπαλλάξειε τὴν σφοδρότητα καὶ τὸ μέγεθος, ἔνδοσιν τοῦ πυρετοῦ λαμβάνοντος· τὴν δὲ πυκνότητα τῶν σφυγμῶν ἀρχομένων τε τῶν πυρετῶν πρώτην συνίστασθαι καὶ συμπαραμένειν μέχρι τῆς τελείας αὐτῶν λύσεως λέγει.

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[79] Daston (2000: 1) has attempted to articulate how objects can be both culturally constructed and naturally real with what she has called applied metaphysics; her insistence on the Aristotelian world of coming-to-be is well placed to deal with features about the emergence, salience, and productivity of scientific objects: "[T]he contrast between pure and applied metaphysics is not necessarily just a reformulation of that between ontology and epistemology, between what is really real and what is dimly known, noumena and phenomena. Applied metaphysics assumes that reality is a matter of degree and that phenomena that are indisputably real in the colloquial sense that they exist may become more or less intensely real, depending on how densely they are woven into scientific thought and practice."

[80] Galen *de dignoscendis pulsibus* 3.3, 8.911K = Herophilus fr. 173.4-5 vS: αὐτὸς δὲ ὁ Ἡρόφιλος πολλαχόθι μὲν ῥυθμῶν εἰς τὰς προγνώσεις μνημονεύει. "Herophilus himself many places mentions rhythms for the purpose of prognoses."

> Herophilus declared that a patient had fever whenever the pulse became more frequent, larger, and more vehement with much internal heat. If therefore [the pulse] should lessen its vehemence and size, the fever is in remission. He says that the frequency of the pulses pops up first when fevers begin and remains so until their final resolution.[81]

Herophilus argued that changes in certain *differentiae* of the pulse show the onset and progress of the fever. The frequency of the pulse is the first sign (πρώτην) of fever and will remain present at its heightened state until the fever is in complete remission. Herophilus wrote that physicians should monitor the vehemence and size of arterial movement to determine the progress of the fever, that is, the physician can use the pulse to make prognoses about the fever. This is significant support for Galen's statement that Herophilus talked of pulses with a view to prognosis.

That Herophilus wrote in *On Pulses* how to use the pulse to make prognoses about the progress of the fever is not surprising, but it is striking that we have no other testimonia about his attempts to use pulse for diagnosis or prognosis in other diseases. The three extant isagogic pulse treatises all list criteria for pulse prognosis in phrenetic, pleuritic, peripneumonic, cardiac, and lethargic patients.[82] Not only does von Staden's (1989) collection of fragments of Herophilus' pulse theory and vascular physiology contain no testimonia relating to these diseases, but in the collection of testimonia relating to Herophilus' therapeutics there is evidence that Herophilus never attempted to treat these diseases. Caelius Aurelianus explicitly states that Herophilus did not write anything about the diseases phrenitis, pleuritis, peripneumonia, or lethargy.[83] There is no

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[81] Marcellinus *de pulsibus* 11, 463 Schöne = Herophilus fr. 182.1-8 vS.

[82] The three isagogic treatises are Marcellinus' *On Pulses*, [Rufus of Ephesus]' *Synopsis On Pulses*, and Galen's *On Pulse for Beginners*. Isagogic treatises show what is minimally necessary for a discourse in Greek pulse theory. All treatises have the following five categorical contents in common, though they often differ in specifics: what pulse is and how it arises, pulse *differentiae*, pulse differences in age groups, pulse in patients with diseases, and certain pulse names. The treatises discuss phrenetic, pleuritic, peripneumonic, cardiac, and lethargic patients at Marcellinus *de pulsibus* 25, 465-6 Schöne; [Rufus] *synopsis de pulsibus* 4, 223-225 Daremberg/Ruelle; Galen *de pulsibus ad tirones* 8.477-92K.

[83] Herophilus frr. 239-244 vS. This is not a chance observation on Caelius Aurelianus' part; indeed von Staden (1999c) shows that Caelius Aurelianus was very well acquainted with Hellenistic medical treatises. Von Staden (1999c: 104-05) notes explicitly: "It is noteworthy that, apparently without exception, the Herophilean silences to which Caelius takes exception concern therapeutics. This is conceivably part of a Methodist strategy of positioning oneself, vis-à-vis one's more illustrious predecessors, as concerned above

testimonium relating to cardiac patients in von Staden's collection, and we should probably conclude that Herophilus did not write on that disease either. In light of the negative evidence for Herophilus' therapeutic interest in these diseases, we should conclude that Herophilus did not attempt to use pulse for prognosis for those diseases typical of Greek discourse on pulse theory, except fever.

2.4.2 Therapy

The standardization of pulse rhythms per age-group is half the promise of theoretical medicine, which aims to provide therapy grounded in a theoretical understanding of *physis*. The pulse rhythms attributed to Herophilus by [Rufus of Ephesus] are natural:[84] rhythm seems to be the only *differentia* of the four laid out in the beginning of Herophilus' *On Pulses* (namely size, speed, vehemence, and rhythm) in which the extant evidence shows that Herophilus attempted to provide normative evaluations in the usual terminology of health and illness in Greek medicine, *κατὰ φύσιν* "according to nature" and *παρὰ φύσιν* "against nature" respectively. (If the *differentia* of frequency corresponds to Herophilus' fifth *differentia*, 'amount', then Marcellinus' report of Herophilus' prognosis of fever shows another normative evaluation.[85]) There is further evidence that Herophilus attempted to use the normative basis of rhythm for diagnosis.

> *ἐν δὲ τῷ παραβάλλειν τὸν χρόνον τῆς διαστολῆς τῷ χρόνῳ τῆς συστολῆς, ὡς Ἡρόφιλος ἠξίου, τὸ μὲν ὅτι παρὰ φύσιν ὁ κάμνων ἔχει δυνατόν ἐστι γνωσθῆναι, καὶ πρὸς τούτῳ γε ὅτι μεγάλως παρὰ φύσιν ἢ μικρῶς. αἱ μὲν γὰρ μεγάλαι τῶν κατὰ φύσιν ῥυθμῶν εἰς τὸ παρὰ φύσιν ἐκτροπαὶ μεγάλην σημαίνουσι τὴν βλάβην, αἱ δ' ἧττους μικροτέραν.*

In comparing the time-unit of dilation to the time-unit of contraction, as

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all with efficacious therapy, not with theories or definitions that are of no immediate clinical utility. Caelius accordingly presents himself as never being silent about the paramount purpose of medicine, viz. successful treatment of the ill, even where he encountered only silence in his more famous predecessors. The silence of the great Herophilus and of various famous Herophileans are thus made to serve as a source of the Methodist's own authority."

[84] [Rufus of Ephesus] *synopsis de pulsibus* 4, 223 Daremberg/Ruelle = Herophilus fr. 177.1-2 vS : *ἐροῦμεν πρῶτον τὰς διαφορὰς τῶν φυσικῶς ἑκάστῃ ἡλικίᾳ παρεπομένων σφυγμῶν* "First I will state the *differentiae* of pulses which naturally attend each age-group." The discussion of pulse rhythm attributed to Herophilus follows this passage.

[85] I am treating 'frequency' as a separate authentic *differentia* unenunciated at the beginning of *On Pulses*. See footnote 59.

> Herophilus thinks is good, the fact can be recognized that the patient is unnatural [*παρὰ φύσιν*] and moreover unnatural to a large degree or to a little. For large changes of natural [*κατὰ φύσιν*] rhythm into an unnatural state indicate great harm but lesser changes lesser harm.[86]

The comparison between the time-units of arterial motion is pulse rhythm, the ratio of the length of dilation to that of contraction. Normative rhythm is a measurement of health and illness. The extent of a pathological state is thus the extent of the pulse rhythm's variance from the norm per age-group.

Here we have theoretical medicine's appeal to medical technicians and practicioners at large postulated in 2.1.1. Measuring pulse rhythms against norms is Herophilus' diagnostic technique for pathological states. The normative categories Herophilus provided offer the medical practitioner the standardized *physis* with which to ground his diagnostic practice. The Herophilean physician stands ready to feel the pulse of his patient and rate it against the expected pulse of the patient's age-group.[87]

Herophilus seems to have given at least one example of his pulse diagnostic technique.

> *οὐ γὰρ μόνον φλεβοπαλία παιδικὴ γέροντι κακὸν, ἀλλὰ γεροντικὴ παιδί. δέκα γοῦν χρόνων τῶν πρώτων, ὡς Ἡρόφιλος ἐμέτρει τοὺς σφυγμούς, εἰ παιδίῳ γενηθείη*[88] *ποτὲ τὸ μεταξὺ δύο πληγῶν διάστημα, ψύξεως ἐσχάτης καὶ διὰ τοῦτο καὶ νεκρώσεως ἐστι σημεῖον· ὥσπερεὶ γέροντι πάλιν παιδίων σφυγμὸς, ἐν ᾧ τῆς διαστολῆς ὁ χρόνος ἴσος ἐστὶ τῷ τῆς συστολῆς, ἐκπεπυρῶσθαι σημαίνει τὴν φύσιν.*
>
> For not only is the arterial pulsation of children bad in an old man, but an old man's pulse is [bad] in a child. So if ever the interval between two beats were of ten primary time-units, as Herophilus measured pulses, it is a sign of extreme chilling and therefore death. Again just as for an old man the pulse of children in which the time of dilation is equal to that of contraction means his nature is aflame.[89]

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[86] Galen *Synopsis de pulsibus* 14, 9.470-1K = Herophilus fr. 175 vS.

[87] Herophilus' patients discussed in the fragments of his pulse theory include children (Herophilus frr. 179, 180, 181, 184.42-44 vS), old men (Herophilus frr. 176, 178 vS), a eunuch (Herophilus fr. 170 vS), and patients with fever (Herophilus fr. 182 vS).

[88] *γενηθείη* De Lacy *apud* von Staden (1989: 352) : *γεννηθείη vulg.*

[89] Galen *Synopsis de pulsibus* 21, 9.499K = Herophilus fr. 178 vS. There are many strange things about the diction used here. For instance, *φλεβοπαλία* is a very old term for Galen (seemingly inappropriate with the literal meaning *vein-palpitation*), attested beyond here only as Democritus' term for the motion of the arteries; see LSJ *s.v.* Moreover, *ἐκπεπυρῶσθαι* has Hippocratic roots but, by Galen's time, one would think more readily of Stoic theories of the cosmos; see LSJ *s.v.* II.1 and II.3.

Herophilus has observed an old man with a pulse rhythm of ten primary time-units between pulse beats: as von Staden (1989) saw, the length of contraction must be ten units long, hence the ratio of dilation to contraction will be 1:10.[90] Clearly, this is a pathological pulse rhythm. When the Herophilean physician compares this pathological pulse rhythm to the normal pulse rhythm of an old man, which would be 1:2 according to [Rufus of Ephesus]' description, it differs by a factor of 5. If this pathological pulse rhythm occurred in a child and were compared to a normal pulse rhythm of a child, which would be 1:1, it would differ by a factor of 10. Rated against the expected categories of pulse rhythm within the normative *physis* of the patient's age-group, this ten time-unit pulse is very pathological and the patient highly diseased.

As a diagnostic and prognostic tool, the pulse is capable of sign-inference. In the above passage, the extreme duration of the contraction is the manifestation of a low vital faculty of pulsation. The low vital faculty is in turn a mark (σημεῖον) of the lack of bodily heat and the nearness of death. The affliction in this case, low internal heat, is entirely internal; there are seemingly no outward signs of disease. In Marcellinus' report of fever discussed above in 2.4.1, the increased frequency of the pulse, implying the patient's increased internal heat, is the primary sign of the fever. In that passage too there was no external mark of disease. The only visible material propery, arterial movement, yields a semiotics capable of describing *physis*. The semiotics (σημαίνει) to which the pulse's diagnosis gives rise specify entire conditions of the body, all without opening it up as in dissection and vivisection.[91] The potential of the pulse as a materio-semiotic object to see into worlds unknown is the tool Herophilus used to promote the therapy of theoretical medicine. The unknown world which Herophilus' pulse theory scouts is the interior of the body. The pulsating artery under Herophilus' finger correlates to interior

[90] Von Staden (1989: 281.n147). By 'interval between pulse beats' Galen appears to mean the time from one part of the arterial cycle to the next, i.e. either from dilation to contraction or from contraction to dilation. Since in [Rufus of Ephesus]' discussion of normal pulse rhythms the elderly have a longer contraction than dilation, 'interval between pulse beats' here must refer to the time from contraction to dilation.

[91] Galen *Synopsis de pulsibus* 21, 9.499K = Herophilus fr. 178 vS.

bodily states that neither the physician nor patient can see: the pulse provides a semiotic sign of a patient's interior constitution, his *physis*, and its changes from normalcy.

2.4.3 From Object to Ideology

The most surprising result from the investigation of Herophilus' pulse theory is the lack of evidence about Herophilus' attempts to use his pulse theory for diagnostic or prognostic purposes except in fever. The failure to find evidence for Herophilus' interest in a therapeutic interest in the pulse beyond fever is all the more surprising in light of the sociological model of ANT. As was stressed above in 2.1.1, new theoretical information in science is liable to be ignored without attempts to network older objects into the system and to network the aims of disparate social groups. I suggested that Herophilus could have stressed the therapeutic implications of his pulse research in order for his theory to be taken up by other medical practitioners. That we have found so little direct evidence of this aim initially suggests that the audience for Herophilus' *On Pulses* did not include the medical practitioners who would have found Herophilus' pulse theory useful for prognosis. Consequently, as stated in chapter 1.2.3, phenomena of cross-scientific appropriation such as Herophilus' pulse-theory are the work of historical elite scientific actors aimed at elite scientists.

Herophilus' pulse theory is the physiological equivalent of Herophilus' work on anatomy. Herophilus discovered the ventricles of the brain, nerves, the membranes of the eye, the epididymis, the ovaries and the fallopian tubes while investigating nearly the entirety of the brain, the digestive system, and the reproductive organs.[92] Herophilus investigated the anatomy of the interior of the body by dissection and vivisection; he also investigated the physiology of the interior of the body by pulse theory. Herophilus clearly believed that it is possible to know about the interior of the body, its state and its function. This is the ideology of Rationalist medicine, to use the name given to Herophilus and his followers by their later medical opponents the Empiricists.

In other words, there is an ideological consequence to Herophilus' pulse theory. Galen's reading of Herophilus' pulse theory makes this clear.

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[92] Von Staden (1989: 138-81).

ἑξῆς δ' ἐστὶν ἐπί γε τῇ τάξει τοῦ λόγου περὶ ῥυθμῶν διελθεῖν, ὑπὲρ ὧν Ἡροφίλῳ μὲν ἐπὶ πλέον εἴρηται τήρησίν τινα καὶ ἐμπειρίαν ἱστοροῦντι μᾶλλον ἢ λογικὴν μέθοδον ἐκδιδάσκοντι. τοὺς γὰρ καθ' ἑκάστην ἡλικίαν ὡς τὸ πολὺ φαινομένους ῥυθμοὺς τῶν σφυγμῶν ἔγραψε, πρῶτον μὲν οὐδ' ἐφ' ὧν τινων φύσεων ἐτήρησεν αὐτοὺς οὐδὲν ἡμῖν εἰπών· εἶτ' ἐξ αὐτῶν ὧν διδάσκει δῆλον ὅτι συγκέχυταί τε καὶ ἀδιάρθρωτός ἐστι περὶ τὴν τῆς συστολῆς τε καὶ τῶν ἠρεμιῶν διάγνωσιν.

> Next in the order of my account it is time to consider rhythms, about which Herophilus spoke at length, making an observation and investigating experience more than teaching a 'Rational' method. For he wrote the rhythms of pulses as they appeared in each age-group for the most part, although not saying at first to us in the case of whose natures he observed them; then from what he teaches it is clear that he is confused and inarticulate about the distinction of contraction and the rests.[93]

Galen invokes the language of the Hellenistic debate between Rationalist and Empiricist sects, a debate we will consider in chapter 4.3. To Herophilus, the Rationalist, Galen gives all the buzzwords of Empiricism – *τήρησις*, *ἐμπειρία*, *ἱστορία*, in Empiricist terms, "personal observation, experience, investigation of previous physicians' reports" – while denying that Herophilus taught in a Rationalist way. This is Galenic irony. We have seen that while Herophilus practiced much observation and personal inquiry, he did little healing beyond fevers and had almost no predecessor's views on the pulse to consult. Indeed Herophilus' pulse theory is largely *de novo*. Galen's aim is to argue that Herophilus is confused about contemporary Rationalist (that is, Galenic) understandings of the pulse.[94] Herophilus may not have been as clear as Galen wished in *On Pulses* but the theory of arterial pulsation was in no way an Empiricist enterprise.[95]

On the contrary, Herophilus' pulse theory, as we have seen, is a deeply Rationalist project, part of the Rationalist investigation of the inside of the body. The treatise *On Pulses* founds a discourse of bodily semiotics. Herophilus' pulse theory is based on new distinctions between types of bodily involuntary motions, properties specific to arterial

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[93] Galen *de preaesagitione ex pulsibus* 2.3, 9.278K = Herophilus fr. 176 vS.

[94] See Appendix A for Galen's attempts to distinguish his pulse theory from Herophilus'. In this passage Herophilus avoided talk of rests and believed that he perceived arterial contraction, whereas Galen used the terminology of rests and believed that not the entirety of arterial contraction could be perceived.

[95] See Galen's comment on Herophilus' style in *On Pulses*: "but as is the custom with Herophilus, in an unclear explanation" *ἀλλ' ὡς ἔθος Ἡροφίλῳ, δι' ἑρμενείας ἀσαφοῦς.* Herophilus fr. 150.12 vS.

motion, and the creation of a new type of materio-semiotic object. Pulse theory is undergirded by appeal to the natural phenomena of anatomy and musical temporality and by appeal to social phenomena of medical therapeutics founded on a theoretical understanding of *physis*. I therefore suggest that Herophilus' pulse theory has a distinctly cultural aim: the emergence of a new programmatic understanding of ἰατρική "medicine" within the community of medical practitioners.

INNOVATION AND TRADITION

Chapter 3: Archimedes' *Ephodos*

This chapter argues that Archimedes' *Ephodos* offers both innovative and traditional science; *Ephodos* 426-438 explains the crucial views of the entire extant text. I argue that *Ephodos* presents a new approach to determining mathematical areas and volumes by selectively integrating mechanical objects and principles into mathematics; I call this new approach a scientific way of seeing. I focus on the logical principles and repeatability of Archimedes' procedure. I show that, despite his innovation, Archimedes continues to prioritize Euclidean-style formalism in mathematical argumentation, the mathematical community's standards of logical formalization.

3.1 Introduction to Archimedes' *Ephodos*

Since there is no modern critical edition of the text of Archimedes of Syracuse's[1] *Ephodos*, I use my own text as the basis of my discussion in this chapter. Appendix B contains a critical edition of the Greek text from the beginning of the treatise through the end of the first proposition and a translation with a limited commentary. For discussion of passages of the *Ephodos* not contained in Appendix B I use the manuscript transcription made publically available online by Reviel Netz and his collaborators.[2]

But there is no critical edition of the manuscript diagrams of Archimedes' *Ephodos* and the diagrams printed in this chapter *may not* reflect manuscript evidence. By showing the fundamental importance of diagrams to Greek mathematics Netz (1999b)

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[1] Archimedes of Syracuse, c. 287-212 BCE, was the leading Greek theoretical mathematician of the third century BCE. In his eleven surviving works – *On the Sphere and Cylinder, Spiral Lines, Conoids and Spheroids, Measurement of the Circle, The Sand Reckoner, Planes in Equilibrium, Quadrature of the Parabola, On Floating Bodies, Stomachion, Cattle Problem,* and *Ephodos* – Archimedes undertakes a range of mathematical problems, primarily with a focus on areas and tangencies. The *Cattle Problem* is transmitted separately from the rest of the surviving Archimedean corpus; a mathematical poem, its authenticity is doubtful. For Archimedes' surviving and non-extant works and their authenticity see Netz (2004a: 10-13). Dijksterhuis (1987) is the best mathematical introduction to Archimedes.

[2] I cite the transcription by folium and line as Netz et al. (2008). (The xml file publically released online must be converted into a pdf file by a LaTex program in order to view page numbers in the transcription.)

launched a revolution of mathematical historians editing critical editions of manuscript diagrams.[3] Netz (2004a) is the first volume of a project to establish critical editions of the diagrams for the entire text of Archimedes; we await his critical edition of the diagrams of *Ephodos* and *Quadrature of the Parabola,* the Archimedean treatises this chapter discusses. Therefore, in the meantime, I reprint Heiberg's (1913) diagrams from his edition of Archimedes: thus I call Heiberg's diagrams "illustrations" rather than "figures".

Since Archimedes is concerned with solids of revolution mostly drawn from conic sections in the *Ephodos*, I provide here a brief background on Greek mathematicians' generation and naming of conic sections.

Greek mathematicians recognized three conic sections: the παραβολή "parabola", ἔλλειψις "ellipse", and ὑπερβολή "hyperbola".[4] Illustration 4 shows the generation of a parabola from the modern mathematical definition of the focus and the directrix.[5]

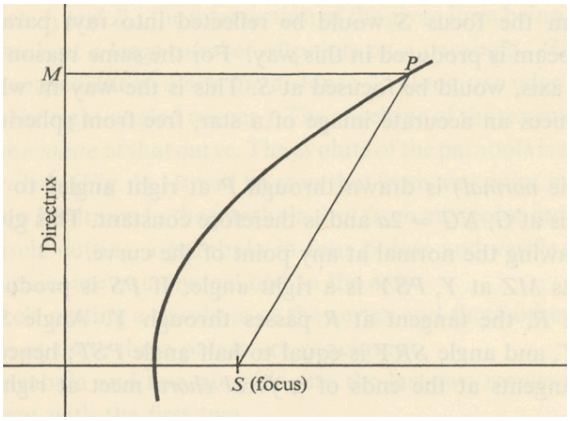

Illustration 4: Focus and Directrix Generation of a Parabola.[6]

[3] Netz (1999b: 12-88). For further research on manuscript diagrams in the text of Greek mathematicians, see Netz (2004a: 8-10) for Archimedes and Saito (2006, 2009) for Euclid.

[4] Dijksterhuis (1987: 55-108) is a good guide to Greek conic sections; see also Toomer (1976).

[5] In the generation of all conic sections the focus is a fixed point and the directrix a straight line not containing the focus whose corresponding conic section consists of all points whose distance to the focus equals their distance to the directrix multiplied by a real positive number, called the eccentricity of the conic section, where the eccentricity of an ellipse lies between 0 and 1, the eccentricity of a parabola is 1, and the eccentricity of a hyperbola is greater than 1.

[6] Lockwood (1961: 5). The illustration shows a parabola, *P*, the set of all points equidistant from the focus, the point *S*, and from the directrix, the line *M*.

Greek mathematicians did not define conic sections by the modern definition of focus and directrix but rather by the conic sections' ability to apply figures to a given figure. (That is, the conic sections were used like a compass and ruler by Greek mathematicians to construct geometric shapes similar to the ones at hand for the mathematician.) The parabola (from *παραβάλλειν* "to apply"), applies the same figure exactly, the ellipse (from *ἐλλείπειν* "to fall short") applies a figure falling short of the given figure, and the hyperbola (from *ὑπερβάλλειν* "to exceed") applies a figure exceeding the given figure. The curves were given their present names by Apollonius of Perga in his *Conics*, written around 200 BCE, from their property of application.

Before Apollonius the curves were named from the process of generation from different types of cones: the parabola was called *ὀρθογωνίου κώνου τομή* "section of a right-angled cone"; the ellipse was called *ὀξυγωνίου κώνου τομή* "section of an acute-angled cone"; and the hyperbola was called *ἀμβλυγωνίου κώνου τομή* "section of an obtuse-angled cone". These were the names used by Archimedes and his contemporary mathematicians in the third-century BCE.

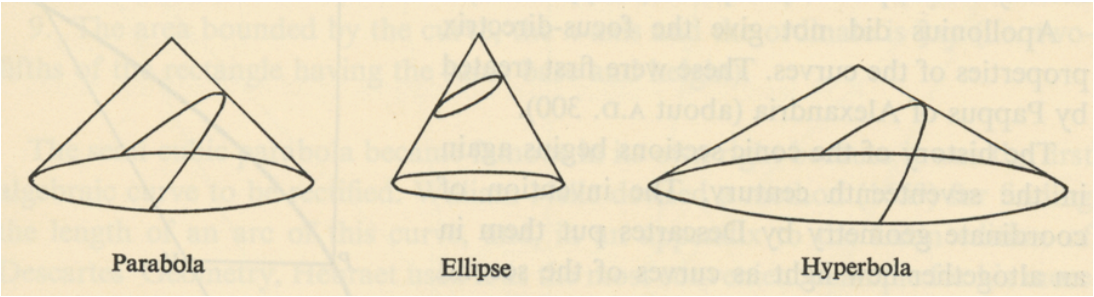

Illustration 5: Conic Sections Generated from Right-Angled, Acute-Angled, and Obtuse-Angled Cones.[7]

Each cone was formed by rotating a right triangle about one the sides adjacent to the right angle to create the onomastic angle at the cone's vertex. The cone then is cut perpendicular to its side surface by a plane. The planar section of the cone cut by the plane is one of the three conic sections, depending on the type of cone. Illustration 5 shows pre-Apollonian Greek mathematicians' generation of the conic sections from their respective cones.

[7] Lockwood (1961: 9).

3.1.1 Title

The manuscript title of Archimedes' *Ephodos* is περὶ τῶν μηχανικῶν θεωρημάτων πρὸς Ἐρατοσθένην. ἔφοδος, usually translated *The Method of Mechanical Theorems to Eratosthenes* and known under the title *The Method*.[8] Although earlier editors did not read the period in the manuscript title, we ought to mark it because it separates ἔφοδος from the address to Eratosthenes, implying that the treatise was known under two titles. The only Greek citations to the *Ephodos* occur in Suda θ 142, as ἐφόδιον, and in Hero's *Metrica*, where the treatise is referred to as ἐν τῷ ἐφοδικῷ. No one ever refers to Archimedes' treatise as περὶ τῶν μηχανικῶν θεωρημάτων πρὸς Ἐρατοσθένην, but rather only by a cognate adjective of ἔφοδος. Therefore, our translation of the title ought to be *On Mechanical Theorems to Eratosthenes*. [or] ἔφοδος – the final word I leave untranslated for the moment.

I argue that ἔφοδος is the original title of Archimedes' work and that a later editor or scribe added the descriptive title περὶ τῶν μηχανικῶν θεωρημάτων πρὸς Ἐρατοσθένην.[9] The fact that ancient authors only cite Archimedes' *Ephodos* by adjectival forms of ἔφοδος suggests that the first half of the title, περὶ τῶν μηχανικῶν θεωρημάτων πρὸς Ἐρατοσθένην, was not part of its original circulation. Also suggestive is the fact that the word ἔφοδος does not appear in the extant text and is therefore unlikely to have been chosen as a title later. Furthermore, some of Archiemdes' works have distinctive and playfully evocative titles, e.g. ψαμμίτης "*Sand-Reckoner*" and στομάχιον "*Stomachion*". The treatise could well have been titled ἔφοδος in a similar jeu d'espirit.[10]

Scholars have taken ἔφοδος to mean "method", a translation promoted by scholars' interest in the methodological purport of the treatise.[11] From Heiberg's (1879)

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[8] Appendix B *Ephodos* (hereafter referred to as *Ephodos*) lines 1-3. Netz et al. (2008: 46r2.1-3) read περὶ τῶν μηχανικῶν θεωρημάτων πρὸς Ἐρατοσθένην. ἔφοδος. Heiberg's text (1913: 426.1-2) prints περὶ τῶν μηχανικῶν θεωρημάτων πρὸς Ἐρατοσθένην ἔφοδος without comment. The translation "*The Method of Mechanical Theorems to Eratosthenes*" comes from Dijksterhuis (1987).

[9] The obvious culprit is Theodosius of Byzantium, a 2nd century BCE mathematician who wrote the commentary on the *Ephodos* recorded by the Suda. See Appendix B.

[10] See Netz (2009a) on playfulness as an aesthetic principle in Hellenistic mathematics.

[11] It is instructive to consider the conception of the contents of the *Ephodos* before the text of the treatise was discovered in 1906. Since Hero's *Metrica* was unknown until 1896, early scholarship had only Suda

dissertation onward, scholarship ignored the metaphoric sense of "journey" inherent in ἔφοδος. Mugler (1958), the standard dictionary of Greek mathematical terminology, offers "*methodus, méthode, methode, method*" for ἔφοδος and explains "le nom désignant l'ensemble des procédés orientés vers la solution d'un problème de mathématiques."[12] Thus the term in the picturesque part of the title lays stress on the methodic import of the treatise; and when combined with the title's first half, gave an impression of a systematic, perhaps even algorithmic, transformation of mechanical results to pure mathematics. But this is a false impression of the systematicity of Archimedes' work, and also a false impression of a simple transformation of results from applied to pure mathematics.

Netz (2009a) notes that the common translation of ἔφοδος as "method" does not capture the resonance of Archimedes' title.[13] This was first pointed out by Eberhard Knobloch (2000), who suggested that Archimedes' title retained the usual sense of the word, "approach". Knobloch writes, "Whenever he spoke of the method we nowadays call [the] 'mechanical method' in this treatise, he used the word τρόπος, not ἔφοδος, without ever adding the attribute μηχανικός, mechanical. In my opinion, we should not ignore this nuance of meaning."[14] Netz furthers Knobloch's point by explaining what "approach" means in this treatise: "Archimedes' treatise was not about some method whereby results can be gained; it was about the principle that one can find a certain

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entry θ 142 to work from. (The Suda has no entry on Archimedes.) Heiberg (1879: 32) is a good précis of older views before the appearance of the *Metrica*: "ἐφόδιον apud Suidas. Theodosius mathematicus clarus traditur scripsisse ὑπόμνημα εἰς τὸ Ἀρχιμήδους ἐφόδιον. Riualtus hinc fingit, Archimedes singulari libro iter suum in Aegyptum descripsisse; sed neque ἐφόδιον hoc sensu accipi potest neque talia Archimedes scripsisset aut Theodosius commentariis illustrasset. Potius crediderim, ἐφόδιον esse librum methodi mathematicae scientiam complectentem, fere eiusdem generis, cuius erat ψευδαρίων Euclidis (Proclus comm. p. 70); ἔφοδος enim post Aristotelem significat methodum." Heiberg's argument against Rivaltus (who wrote a life of Archimedes in the 1615 Paris edition of Archimedes' works according to Heiberg (1879: 5)) turns on the meaning of ἐφόδιον, from its literal meaning of 'travel money' to Heiberg's understanding of it an adjectival form from the noun ἔφοδος. Heiberg's view of the contents of the *Ephodos* is of course correct but so is Rivaltus's literal translation of ἐφόδιον, despite Heiberg's protests. It therefore seems strange that no one (Adler (1931: 693 θ 142) records no emendation) has suggested the obvious correction of the Archimedes's title in the Suda passage, ἐφοδι<κ>όν, a form which corresponds exactly to the *Metrica* title and is used only to refer to methodological concerns.

[12] Mugler (1958: 211 *s.v.*). Contrast this with Mugler's (1958: 282 *s.v.*) definition of μέθοδος, which again is a group (ensemble) of procedures directed toward "une construction ou un résultat déterminés."

[13] Netz (2009a: 157) argues that *ephodikon* is the true Archimedean title by comparing to the titles *anaphorikon* of Hypsicles and *okutokion* of Apollonius.

[14] Knobloch (2000: 83).

approach to a problem, even without solving it in a completely satisfactory way."[15] What is at stake, then, in the *Ephodos* is not a methodological heuristic, as it were *The Method*, but rather *an approach* to problem-solving. Knobloch's warning serves to prevent a modern translation from predetermining our expectations of a Hellenistic self-reflective scientific treatise; and therefore I will refer to Archimedes' treatise in transliteration alone as the *Ephodos*.

3.1.2 Framing the *Ephodos*

The *Ephodos* opens with an introductory letter to Eratosthenes.[16] It seems from the introductory letter that Archimedes had earlier informed Eratosthenes about his method and now illustrates it to him, and is communicating to the broader Alexandrian mathematical community through Eratosthenes. Formally, of course, the *Ephodos* is addressed to Eratosthenes alone. But we would be naïve readers with a poor sense of the social cachet of novel solutions in the competitive milieu of science in the Hellenistic period to believe that Archimedes did not intend his writings to circulate beyond the nominal addressee. The intended audience is clearly wider than Eratosthenes, although he is perhaps a sympathetic recipient because of his own work on the integration of mechanical principles into mathematics.

Archimedes writes as though he is the first to use his approach, since he implies that it is not known to the broader mathematical community. Archimedes illustrates his approach with individual mathematical propositions alluding to his own mathematical publications, to which he occasionally refers explicitly. In this way Archimedes might intend his *Ephodos* to be a reflection and capstone of his entire mathematical œuvre, including his earlier work in mechanics such as *Quadrature of the Parabola* and *Equilibrium of Planes.*[17] The 'methodological' focus of the treatise is heightened by

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[15] Netz (2009a: 157).

[16] Eratosthenes is also the named recipient of Archimedes' *Cattle Problem*, an intellectual challenge in epigram.

[17] Scholarship has taken the internal references in the *Ephodos* to Archimedes' other works to indicate the historical dating of Archimedes' work; thus the *Ephodos* appears usually last in lists of Archimedes' works. For example see Dijksterhuis (1987: 46-47). Indeed, whether we adopt the ordering of Archimedes' treatises from Dijksterhuis (1987), the older sequence, or Knorr (1978) and Sato (1986-87), the *Ephodos* remains among the last treatises of Archimedes' career.

Archimedes' passing reference to his previous result on parabolic quadrature in the opening letter. As I will argue in a close reading of the first proposition in 3.2.3, Archimedes' novel presentation of this result in the *Ephodos* offers up its didactic intent only when the mechanical method of his earlier treatise, *Quadrature of the Parabola*, is treated as an intertext. This is intertextuality$_A$ as will be shown in 3.2.2.

Archimedes claims to have sent an earlier letter to Eratosthenes in the form of an intellectual challenge (a common conceit in Hellenistic mathematics).[18] The solutions that Archimedes challenged Eratosthenes to prove were that the volume of a section of a right circular cylinder cut by a plane diagonally through the center of the circle at the cylinder's base, now called a cylinder hoof, is one-sixth of the volume of the encompassing prism and to prove that the volume of two intersecting right circular cylinders, now called a bicylinder, is two-thirds of the volume of the encompassing cube.

In addition to the pure mathematical interest in Archimedes' ability to determine the volumes of complex solid figures, the *Ephodos* is most famous for our glimpse inside Archimedes' "mathematical workshop":[19] novel features include the application of mechanics to geometry (paralleled in other Archimedean works), the use of indivisibles and actual infinities,[20] and Archimedes' meta-mathematical comments. Some commentators have seriously maintained that *Ephodos* is a heuristic text.[21] Yet given the polemic practices of Greek scientists, it makes little sense for a scientist give away his determinative procedure.[22] Furthermore, reading *Ephodos* as a treatise revealing Archimedes' hidden knowledge smacks of the obsession of 17th century mathematicians for an ancient *ars invendi*.[23] In short, the fantastic reading of the *Ephodos* as a heuristic for broader Archimedean material is not justified by the treatise itself nor the context of its publication.

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[18] *Ephodos* 5-10.
[19] From Dijksterhuis (1987: 315), but the phrase goes back to Heiberg-Zeuthen (1907: 342).
[20] See especially Netz, Saito, and Tschernetska (2001) who claims use of actual infinities is unparalleled in Greek mathematics, but Acerbi (2007: 88) disputes this.
[21] See Knorr's comment in Dijksterhuis (1987: 436): "[I]t provides unique insight into his heuristic methods."
[22] See Netz (2000) for a treatment of mathematical analyses, which were long supposed to be heuristic texts.
[23] See Jones (1986: 572) and Netz (2009a: 79.n14).

Critical passages of Archimedes' own views about the aim and purpose of the *Ephodos* appear at the end of the introductory letter to Eratosthenes and later between propositions 1 and 2.[24] (Heiberg (1913) inserted the numbering of the propositions into the critical text and the numbers are useful for reference purposes.[25]) Netz (1999b) suggests reading this final meta-mathematical passage as part of the introduction – letter, first proposition, and final meta-mathematical statement – so that the methodological interest of the treatise, its "second-order discourse", subordinates the mathematics of proposition one, which is already proved in *Quadrature of the Parabola*.[26] The first proposition proceeds unusually slowly and carefully, and often "looks-backward" to the axioms for its justification.[27] In Netz's words, "Proposition 1 is an example of a way of proving, not just a proof."[28] This is a very inviting interpretation: the known result, the previous use of the mechanical method in *Quadrature of the Parabola*, and the two-dimensionality of the proposition 1 – when the rest of the treatise is concerned with three-dimensional figures – all support Netz's point.

Despite the attractiveness of Netz's interpretation, the absence of a formal conclusion to the introductory letter is troubling. Archimedes' usual practice is to include all his extra-mathematical comments, if any, in the introduction to a treatise.[29] The introductory letter, if it had a formal conclusion, must end at the gap between the end of

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[24] *Ephodos* 276-285.

[25] Netz, Saito, and Tschernetska (2001: 11n.5). Also see Netz (1999b: 94) for an explanation of how Heiberg's editorial insertion of numbered propositions affects the natural flow of the language.

[26] Netz (1999b: 213). *Ephodos* proposition 1 is Netz's second example of the compartmentalization of mathematical discourse after Arist. *Met.* 373a; these are the 'exceptions' that prove the rule, for both authors are trying to embed mathematics within a larger philosophical point. Netz (1999b: 214) ends this section with his dictum "When one does mathematics, one does nothing else", repeated in Netz (2004a).

[27] See Netz (1999b: 198-204) for the concept of "backward-looking" and Netz (1999b: 212) for his logical tree analysis of proposition 1.

[28] Netz (1999b: 213).

[29] All but one of the introductory letters in the treatises addressed to Dositheus (*Spiral Lines*) ends with a word of farewell (εὐτύχει, ἔρρωσο, or ἐρρωμένως) that formally closes the letter before the mathematical content. Netz's (2009a: 3-4) reading of the narrative aesthetics of *Spiral Lines* notes the opaqueness of the introductory letter; he also notes the absence of a connective particle in the first proposition. I suggest that the absence of a word of farewell is an equally dramatic indication of the speed and discursiveness of *Spiral Lines*. (The first proposition of an Archimedean treatise usually opens without a connective participle to any previous opening.) Wilamowitz (1894=1971: 50n.1) in analyzing the possibly contemporaneous letter of Eratosthenes to Ptolemy seems to confirm Archimedes' practice from broader reading: "Am Schluß ist εὐτύχει oder ἔρρωσο schlechthin obligatorisch für jeden Brief jener Zeit."

the formal letter and the beginning of the postulates. For there is no space available in the transcription of the manuscript to have a formal conclusion between the meta-mathematical observation and the beginning of proposition 2,[30] which in fact begins mid-line as ἐ<κ>δοθεῖσαν πρότερον. ὅτι δὲ πᾶ-.[31] In general the manuscript only allows for breaks between propositions and then only when the text is separated by the mathematical diagrams. Therefore if the introduction had a formal conclusion it could not have fallen after the meta-mathematical observation. Archimedes' preferred closings of εὐτύχει, ἔρρωσο, or ἐρρωμένως could fit cleanly into the lacuna read by Heiberg (1913) of twelve letters supplemented as <σοι πρότερον> at the end of the introductory letter before the postulates.[32]

Yet any argument about the formal structure of the opening letter cannot overlook the fact that Archimedes includes meta-mathematical observations and a methodological focus beyond the opening letter. The structure of the surviving text of the *Ephodos* is: opening letter, postulates, proposition 1, meta-mathematical observations, mechanical propositions 2-11 on individual objects (including mechanical demonstrations of volumes of spheroids and paraboloids of revolution proved before in *On Conoids and Spheroids*), and the final extant propositions 12-15 that prove the volume of the cylinder hoof. The final sequence of four propositions is more developed than the earlier, previously-proved results: propositions 12 and 13 are proved with mechanics and indivisibles, proposition 14 with indivisibles alone, and proposition 15 is proved in formal Euclidean style. It seems likely that Archimedes proved the volume of the bicylinder in a similar sequence in propositions 16-18; i.e. mechanics and indivisibles, indivisibles alone, and a formal Euclidean proof.[33] Netz, Saito, and Tchernetska (2001) have suggested Archimedes may have included more meta-mathematical observations in the gap of one missing leaf between the mid-point of proposition 12 and the beginning of proposition 13, the

[30] *Ephodos* 276-285.
[31] *Ephodos* 285.
[32] *Ephodos* 131. It may be too charitable to say that Heiberg *read* a gap of 12 letters; his apparatus *ad loc.* indicates he supplemented based on Reinach's suggestion. See Appendix B footnote 49.
[33] Netz, Saito, and Tchernetska (2001: 11).

transition between mechanics plus indivisibles and indivisibles alone.[34] This is a reasonable proposal and gains strength from the insertion of other meta-mathematical observations between propositions 1 and 2. If Archimedes did include more meta-mathematical comments later in the treatise, the mathematical flow of the *Ephodos* would be interrupted by extra-mathematical material in a way alien to the vast majority of mathematical writing in Archimedes' corpus.[35] Netz's suggestion to read proposition 1 as part of the "second-order" discourse of the *Ephodos* then ought to be extended to cover the majority of the mathematics in the treatise, apart from the final sequence of theorems on the cylinder hoof and bicylinder.

Moreover, the transition from mechanical proposition to mechanical proposition in the *Ephodos* often has the manuscript form θεωρεῖται δὲ διὰ τοῦ τρόπου τούτου καὶ ὅτι.[36] Heiberg (1913) once emended this phrase to θεωρεῖται δὲ τὸν τρόπον τοῦτον καὶ ὅτι.[37] He seems to have understood the manuscript phrase as the adverbial use of τρόπος, i.e. "likewise" or "in this way", and emended accordingly.[38] But I would suggest that we view the manuscript reading as marked vocabulary: Archimedes is reiterating and teaching how to use his method, the τρόπος; the phrase means "It is also seen through this manner that." The phrase first appears after proposition 1 as if to suggest that Archimedes will argue methodically in a manner analogous to the earlier proposition. Netz (1999b) has argued that Greek mathematicians' use of ὁμοίως δεῖξαι in extending and, in our sense, generalizing a theorem, is in fact a generalization of the means of proof and not a generalization of results: ὁμοίως δεῖξαι means that the proof is repeatable with another collection of similar inputs.[39] I argue that a similar effect is occurring here, so that the "backward-looking" proposition 1 establishes in the above-defined sense the proper manner of mechanical argument for Archimedes' τρόπος. Therefore the introductory letter, postulates, proposition 1, and the first set of meta-mathematical

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[34] Netz, Saito, and Tchernetska (2001: 23-24).
[35] The exception is Archimedes' *Arenarius*, for which see Netz (2003).
[36] Netz et al. (2008: 66r2.8, 65r2.20, 58v1.4-5, 45r2.7-8, 160v1.7-8, 48r2.16-17, 41r1.3).
[37] He emends at Heiberg (1913: 438.28) but not at (Heiberg 1913: 446.16, 454.12-13, 458.25-26, 468.25, 474.8-9, 484.9).
[38] LSJ τρόπος II.2.
[39] Netz (1999b: 242-46).

observations become a paradigmatic grouping of didactic instruction to the reader, Eratosthenes and the intellectual circle beyond, for understanding the *Ephodos*. In this chapter I will demonstrate how this grouping outlines the understanding we are to apply to the rest of the text.

3.2 EMERGENCE, OR INTEGRATION

Archimedes' *Ephodos* introduces a novel approach to finding areas of solids of revolution, whereby geometric shapes and the lines that compose them are weighed on a scale-beam. Here is the emergence of a new procedure in a science. ANT, as recounted in chapter 1.4, argued that new concepts in science develop from older concepts and objects embedded in the networked structure of science. In the case of Herophilus' pulse theory in 2.3, the networked structure revealed the interaction between historical mental concepts, culturally conditioned to third century BCE Alexandria, and ahistorical physical phenomena. We are presented with a similar divide between noumena and phenomena in Archimedes' *Ephodos*: Archimedes' approach integrates the sciences of mathematics and mechanics.

The text marks the different sciences while uniting them. In the opening letter of the *Ephodos* Archimedes immediately introduces a contrast between *τῶν ἐν τοῖς μαθημάτεσσιν* "mathematics" and *τῶν μηχανικῶν* "mechanics".[40] He does not call his approach a 'method' but ambiguously refers to *τρόπου τινὸς ἰδιότητα* "a characteristic of a certain manner." His *tropos* – let us simply call it that after Knobloch's (2000) warning – is not identified solely with mathematics or mechanics, but rather is a metaphoric road (*καθ' ὅν ἐπιπορευομένωι*) and its departure points (*ἀφορμὰς*) that connect those separate groups. Archimedes does not describe the *tropos* directly in his introductory letter but merely characterizes its heuristic functions and benefits and

[40] *Ephodos* 69-80: *ὁρῶν δέ τυ, καθάπερ λέγω, σπουδαῖον καὶ φιλοσοφίας προεστᾶτα ἀξιολόγως καὶ τὰν ἐν τοῖς μαθημάτεσσιν κατὰ τὸ ὑποπίπτον θεωρίαν τετιμηκότα ἐδοκίμασά γράψαι τοι καὶ εἰς τὸ αὐτὸ βιβλίον ἐφοδιάσας τρόπου τινὸς ἰδιότητα, καθ' ὅν ἐπιπορευομένωι ἐσσεῖται λαμβάνειν ἀφορμὰς εἰς τὸ δύνασθαί τινα τῶν ἐν τοῖς μαθημάτεσσιν θεωρεῖν διὰ τῶν μηχανικῶν.* "Seeing that you, just as I said, are learned and remarkably preeminent in philosophy and have appreciated happenstance contemplation in mathematics, I thought it good to write to you and to furnish in the same book a characteristic of a certain manner, for one traversing along which it will be possible to supply starting points for the ability to contemplate some of the things in mathematics through mechanics."

alludes to his earlier results with it.

In chapter 1.3.2 I argued that there is technical vocabularly associated with the domain of each particular science. Archimedes' *Ephodos* mixes the technical terminology of the domain of mathematics and the technical terminology of the domain of mechanics. Netz (1999b) has shown that the Greek mathematical vocabularly is relatively small.[41] He has shown that other varieties[42] of mathematical language do not have the same consistency of technical diction as the continuous Euclidean-style – repetition of diction being *the* factor in establishing a consistent Greek mathematical lexicon. Effectively, then, Netz has shown that Greek mathematicians recognized different registers to Greek mathematics: Euclidean-style geometric style is the most regulated and therefore formal register; but arithmetic, mechanics, etc. are much less regulated and therefore less formal. Netz divides technical mathematical language into object formulae (e.g. triangles, lines, points, etc.), construction formulae (e.g. "let be drawn", "assume") , second-order formulae (e.g. "I say that"), argumentation formulae ("the ratio of X to Y"), and predication formulae (e.g. "X is equal to Y with Z").[43] The associated groups of formulaic technical terminology demarcate objects, manipulate them, and consider them individually or conjointly in equalities and proportions. Since Netz has shown that the technical terminology of Greek mathematics is therefore well-regulated and relatively small, the mathematical register of technical terminology is not the marked style of the *Ephodos*; rather, the *Ephodos* marks the register of the mechanical.

While *Ephodos* introduces a new *tropos* to measuring solids of revolution using mechanical procedures, Archimedes had already attempted to measure the parabola using

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[41] Netz (1999b: 89-126).

[42] I adopt the idea of register variation from Willi (2003: 226), a comparative study of linguistic registers in Aristophanes: "It has become clear that it is feasible to operate with categories of variation which are more fine-grained than the well-known ones of 'foreign dialect', 'paratragic style', or 'colloquial language'. The universally recognized absence of linguistic continuity in Aristophanes, and above all the lack of continuous linguistic characterization, should not discourage us from analysing *dis*continuous varieties: first, because variation is an interesting topic in its own right and secondly because linguistic charaterization – if we do want to look for it – is possible even in a discontinuous mode."

[43] Netz (1999b: 133-44). For the sake of readability, I write in the modern shorthand of algebraic substitution; Greek mathematicians refer only to their formulaic geometric objects.

a kind of mechanical procedure in *Quadrature of the Parabola* and *Planes in Equilibrium* 2. Thus, the first proposition of the *Ephodos* – the paradigmatic proposition for understanding the treatise – is Archimedes' third attempt to measure the parabola by a mechanical procedure. Just as in the case of Herophilus' pulse rhythms in chapter 2.2, we have multiple attempts by the same scientist to solve the same problem. However, unlike the methodological consideration of the Herophilean material in chapter 2.2, we have explicit evidence about the chronological sequence of Archimedes' treatises: Archimedes claims to have proven the result of the area of a parabola before the *Ephodos*; thus *Quadrature of the Parabola* and *Equilibrium of Planes*, Archimedes' other mechanical treatises, precede *Ephodos*. Therefore, I suggest that we consider Archimedes' other mechanical treatises as possible intertexts for our reading of *Ephodos* proposition 1. This is intertextuality$_A$ as described in 1.3.1 where the author directs the reader to relevant parallels, variously to elucidate or contrast the present text: thus intertextuality$_A$ is a guide to authorial intent. As a guide to authorial intent intertextuality$_A$ signposts the scientific author's sense of the continuity and contrast between his multiple attempts to solve the same problem. The contrast between Archimedes' different treatises will focus on the role and type of mechanical procedure.

3.2.1 Parabolas and Intertexts

Ephodos has the narrative shape of *Quadrature of the Parabola*, not *Planes in Equilibrium* or *Floating Bodies*, the other Archimedean mechanical treatises. Hence my discussion will focus on *Quadrature of the Parabola*. The mathematical aim of *Quadrature of the Parabola* is exclusively to measure the parabola: the treatise has an introductory letter, several initial propositions (1-5) whose results will be used later, a mechanical argument to measure the parabola using the same parabola BΘΓ (propositions 6-17), and a separate geometrical argument to measure the parabola employing a *reductio ad absurdum* (propositions 18-24). The aim of *Ephodos* proposition 1, the exemplar proof as argued above in 3.1.2, is to measure the area of a parabola. The comparison to the *Ephodos* then is *Quadrature of the Parabola*'s mixture of mechanical and

mathematical. I argue that *Quadrature of the Parabola* functions as an intertext for *Ephodos*: Archimedes invokes the mechanical procedure of *Quadrature of the Parabola* as a cultural discourse of mechanized mathematics.

Netz (2009a) argues that a central narrative principle of Archimedes' treatises is *poikile*: he suggests that Archimedes' "hybrid treatise", the mixing of mathematical genres, is a generic kind of literary work.[44] The Archimedean treatises exhibiting hybridization are *Arenarius, Stomachion, Quadrature of the Parabola,* and *Ephodos*. Netz argues that *Quadrature of the Parabola* as a hybrid treatise engages in a sort of mathematical intertextuality.

> Here is a hybrid treatise, obtaining the same result twice via different routes. Each of the routes is based on hybrids, on cross-fertilization: abstract conic theory and a concrete theory of the balance, in the first route; abstract conic theory and an even more abstract summation of geometrical progressions, in the second route. But in this sense the hybrids do cross-fertilize and in this way form some kind of organic unity. The relationship within each of the segments – propositions 1-18 and propositions 19-24 – is that of a single mathematical thought. Putting the two segments side by side is a much more radical departure, creating a textured treatise whose two parts are to be read alongside, or against, each other. Is the presence of a more "classical" geometrical proof designed to undercut the first, "mechanical" proof? Or are the two meant to cast light on one another (e.g. in that the mechanical line of thought might explain, in some sense, how one obtains the geometrical one? This certainly is the experience of reading the second following the first). The treatise as a whole throws this kind of meta-mathematical puzzle at the reader and, in a sense, ironically undercuts the very notion of a definitive proof: it highlights, after all, the multiplicity of mathematical routes.[45]

Netz highlights the main interpretative problem raised by the parallelism of types of proof in *Quadrature of the Parabola*. When read as a whole, *Quadrature of the Parabola* offers a solution to the same problem twice; the reader expects a geometric proof up until proposition 6 and then remembers the mechanical proof when reading propositions 19-24. Netz suggests that the effect is one of denying the sense of finality and completion to either procedure's solution. In effect Archimedes directs the expectations of the reader away from the immediate proposition: the idealized proof – a

[44] Netz (2009a: 115-173).
[45] Netz (2009a: 130).

final, unassailable sequence of argument about the area of the parabola[46] – acts an intertext, even though such as text is not present at all. We readers need not choose which of the two methods of proof are ultimately intended in *Quadrature of the Parabola*.[47]

In *Quadrature of the Parabola* Archimedes highlights the mathematical expectations for his readers regarding the finality of proof by intertextuality$_A$ as described in chapter 1.3.1. It should not seem strange to talk about intertext here: Archimedes is a self-referential author and Greek mathematical texts constantly refer to previous written works. Scholars are used to talking about intertext primarily as a literary text or trope, which directs the reader's attention toward other written texts to illuminate further the text at hand.[48] Yet the reappearance of a mathematical concept can equally be intertextual: indeed Netz's (2009a) reading of *Quadrature of the Parabola* suggests that an Archimedean intertext may not even need to exist as a document for it to be alluded to. Here "text" should be understood in an expansive sense: generic expectations, including the regimented form of Greek mathematical proof discussed further in 3.2.3, can be understood as a kind of textual discourse, with their own codes and references.[49] An author may mobilize a set of generic allusions which evoke a cultural discourse without reference to a particular written text. The Greek mathematician thus alludes to the objects and intellectual codes of his own domain: a geometrical object, such as the parabola, or a methodic variation, such as a mechanical procedure, or a concept, such as a

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[46] Archimedes' criticisms in *Quadrature of the Parabola*'s opening letter (Heiberg 1913: 262.19) of previous geometers' *οὐκ εὐπαραχώρητα λήμματα, not easily admitted lemmas,* in attempting similar problems ought to be read as a further part of Archimedes' games with his readers about the finality of proof.

[47] Netz (2009a: 128-29) sees this as a deliberate authoritative strategy by Archimedes, in that he shows mastery of both kinds of techniques without explanation: it is the mystique of the superior intellectual competitor. Thus Netz's (2009a) historiographical strategy is a type of intertextuality$_R$ as shown in 1.3.1: the issue of historical chronology between different solutions is put into abeyance, while the reading of a unique kind of reader, the contemporary historian, guides the continuity of authorial thread between the scientist's multiple attempts at solving a problem. Netz's interpretation defends the unity of *Quadrature of the Parabola*. Older *Quellenforschung*-style commentators saw a historical development in Archimedes' mathematical abilities from the two methods of proof and deemed the mechanical procedure the earlier publication; this position is clearly Whiggish historicism.

[48] See the discussion of Hinds (1998) in chapter 1.3.1.

[49] For intertextuality as a schema of generic discourses rather than a particular written text, see Riggsby (2006).

secure proof. Furthermore, intertextuality$_A$ helps to characterize the intended audience. Since it was argued above in 3.1.2 that Archimedes' writings circulated beyond their nominal addressees to the Alexandrian mathematically-literate community, intertextuality$_A$ implies that in *Quadrature of the Parabola* Archimedes assumed an audience of fellow mathematicians.

Let us analyze the mechanical procedure of *Quadrature of the Parabola* for measuring the parabola. In proposition 6 Archimedes enjoins us to "imagine a plane perpendicular to the horizontal" and begins to describe a scale-beam ΑΒΓ constructed in that vertical plane whose fulcrum is point B as shown in illustration 6.

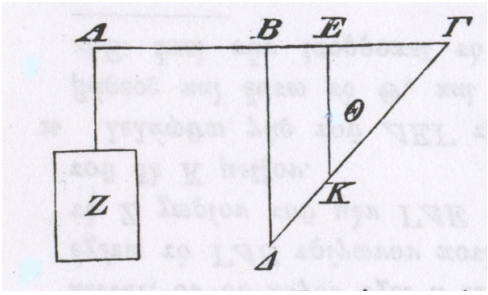

Illustration 6: Heiberg Diagram for *Quadrature of the Parabola* Proposition 6.[50]

At first glance, a scale-beam (*ζυγός*) is a crude machine that produces the (in)equalities 'equal to', 'less than', and 'greater than'. But it is actually a proportional machine which, if always forced to yield the equality 'equal to' such that the machine is balanced, gives a proportion of the sort A : B :: C : D where (A, C) is one of side of the balance and (B, D) is the other side. Illustration 6 shows that the weight Z hung at point A balances the triangle ΒΔΓ, whose center of weight is point Θ, hung at point E. Since weights are inversely proportion to their distances from the fulcrum by the law of the lever, line AB : line BE :: triangle ΒΔΓ : rectangle Z in *Quadrature of the Parabola* proposition 6.[51] Archimedes' mechanical strategy is to balance the machine; his mathematical strategy is

[50] Heiberg (1913: 274).

[51] The text (Heiberg 1913: 274.18-21) describes the act of weighing and the resulting proportion that the diagram illustrates: *ἐπεὶ δὲ ἰσορροπέοντι τὸ μὲν* Z *κρεμάμενον κατὰ τὸ* A, *τὸ δὲ* ΒΔΓ *κατὰ τὸ* E, *δῆλον ὡς ἀντιπέπονθε τοῖς μάκεσιν, καί ἐστιν ὡς ἁ* AB *ποτὶ τὰν* BE, *οὕτως τὸ* ΒΔΓ *τρίγωνον ποτὶ τὸ* Z *χωρίον.*

to manipulate the various proportions produced by the weights and their distance from the fulcrum.

To set two objects on the scale-beam simultaneously would not be fruitful in measuring their ratio. But if the scale-beam is used as a middle proportion machine by balancing the scale-beam, it will determine the ratio between two objects which do not hang together. In *Quadrature of the Parabola* 6-13 Archimedes proceeds to place triangles and trapezoids upon a balanced scale-beam in order to specify geometric ratios between them. Finally, in proposition 14 Archimedes introduces the parabola, specified via triangles and trapezoids, upon the scale-beam to measure it, as illustration 7 shows. Thus in propositions in 14 and 15 Archimedes defines a complex set of equalities between trapezoids to weights unique to larger trapezoids and combined against the triangle, and trapezoids determined within the larger triangle such that the ratio between trapezia remains the same (a geometric series). Given further that the smaller trapezia are encompassed by the larger trapezia, Archimedes is able to define further ratios between smaller trapezia and their encompassing larger trapezia.

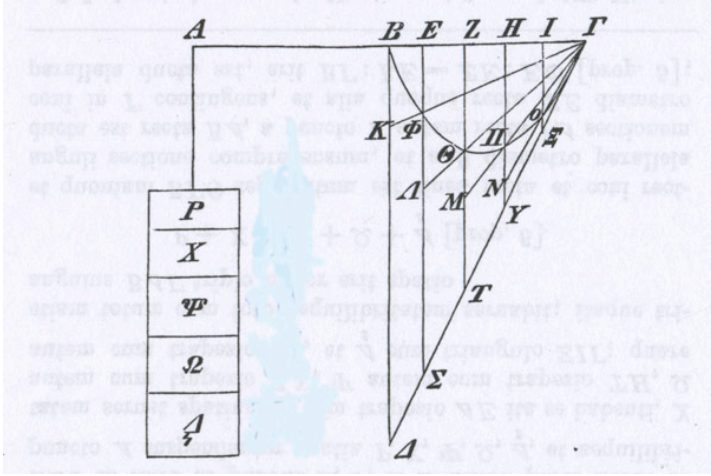

Illustration 7: Heiberg Diagram for *Quadrature of the Parabola* 14.[52]

Since all figures are now defined in relation to each other, Archimedes is thereby able to prove that the area encompassed by the trapezia circumscribing the parabola is greater

[52] Heiberg (1913: 289).

than one third the whole triangle and again the area encompassed by the smaller trapezia is less than one third the whole triangle. This form we recognize as the Archimedean limit, which is proved by double *reductio ad absurdum*; Archimedes does this in proposition 16 without the scale-beam. In proposition 17 Archimedes restates the theorem in terms of the inscribed triangle, the familiar form of the thesis: the parabola is four-thirds of its inscribed triangle.

What then is the "intuitively gained insight"[53] of the mechanical exposition of the *Quadrature of the Parabola*? Past scholarship would seem to regard it as the result of the theorem itself. But the essential point is the geometric progression of the measuring figures – and this comes from the division of the triangle by the trapezia, not from the scale-beam itself. The scale-beam merely preserves the correct ratio of areas in geometric progression. In this way, the scale-beam is a means to an end and not the discoverer of the result.

In the *Ephodos* Archimedes can allude to his earlier work on mechanical procedures *Quadrature of the Parabola* and *Planes in Equilibrium*. While both treatises treat the parabola in a mechanical manner, *Quadrature of the Parabola* mixes the mechanial and mathematical in a similar structure to the *Ephodos*; the *Ephodos* merely repeats as axioms before the first proposition the proofs about barymetric centers from *Planes in Equilibrium*. Therefore I argue that Archimedes alludes to his earlier treatises for different reasons: he refers readers to *Planes in Equilibrium* for its proofs about centers of gravity and to *Quadrature of the Parabola* for its mechanical procedure. Thus the mechanical procedure of *Quadrature of the Parabola* – the physical act of weighing a mathematical object in a way that is very schematically similar to the weighing of objects in a scale pan against sums of standardized weights – is the mechanical procedure Archimedes expects his readers to know in the reading of the *Ephodos*. In the *Ephodos* Archimedes marks mechanical discourse and directs his readers to textual codes of mechanized mathematics from *Quadrature of the Parabola*.

[53] Disjkterhuis (1987: 336).

3.2.2 Appopriating Mechanical Discourse

The historiographical issue in cross-scientific appropriation is how Archimedes integrates the mechanical and mathematical elements into a coherent *tropos*. To address this problem, using the literary tools developed in chapter 1.3 I will describe and analyze the mechanical discourse of the *Ephodos* in 3.2.2. Next, in section 3.2.3, I will do a close reading of *Ephodos* proposition 1 to demonstrate how Archimedes integrates the mathematical and mechanical aspects into a coherent *tropos*.

The *Ephodos*' domain of mechanics, *τὰ μηχανικά*, has the Archimedean sense of mechanized mathematics, distinct from the modern meaning of applied mathematics, i.e. mathematicized mechanics.[54] For example, in the treatises *Quadrature of the Parabola* and *Planes in Equilibrium* Archimedes finds centers of weight of mathematical forms and positions those mathematical shapes on an idealized balance to find their volumes. The distinctly Archimedean treatment of *τὰ μηχανικά* processes mathematical figures according to physical principles, such as weight and solidity. There are three textual elements in Archimedes's discourse of mechanics: the physicalization of mathematical objects, the scale-beam, and centers of weight. The vocabularly of solidity and weighing associated with these elements marks the *Ephodos*' mechanical treatment of geometrical objects.

Physicalizing geometric objects endows them with characteristics they do not normally possess as *τὰ μαθήματα*. By applying Archimedes' *tropos* the *Ephodos* imagines that mathematical objects are balanced on a scale-beam (*ζυγός*). Objects must have mass and thus weight when balanced in the physical world. For example, the text of *Ephodos* proposition 2 imagines that the sphere ΑΒΓΔ, cone ΑΕΖ, and cylinder ΦΨΧΩ have mass, as their cross-section distributed on the scale-beam ΘΑΓ shows in illustration 8. The sphere, cone, and cylinder are composed of circles; that is, the figures are solid.[55]

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[54] Previous scholarship on Archimedes' mechanics focused on whether his derivation of the law of the lever in *Equilibrium of Planes* 1.6 was correct: see Dijksterhuis (1987: 291-304), Drachmann (1967), Palmieri (2008). In my view this has not been a productive discussion in understanding Archimedes.

[55] Netz et al. (2008: 66v2.9-12) *συμπληρωθέντος οὖν τοῦ κυλίνδρου ὑπὸ τῶν ληφθέντων κύκλων καὶ τῆς σφαίρας καὶ τοῦ κώνου.* It should be understood that "fill", *συμπληροῦσθαι*, here is a technical term of Greek mathematics indicating the full construction of a figure for a proof, called the *κατασκευή*: *συμπληροῦσθαι* thus indicates that the figure is completed. See Euclid *Elements* I.8 and Mugler (1958: 392-93).

The text states next that the cylinder HE balances around the fulcrum point A both the sphere ABΓΔ and the cone AEZ when moved to Θ. But this is not the case: it is specifically the cone AEZ embedded in the sphere ABΓΔ which balances, not the two separate objects, for they must have the same center of weight.

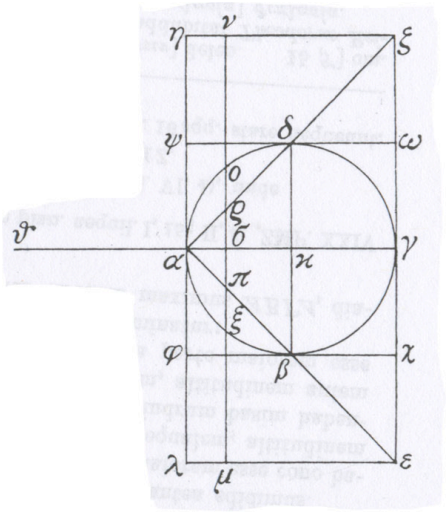

Illustration 8: Heiberg Diagram for *Ephodos* Proposition 2.[56]

That is, the sphere ABΓΔ and the cone AEZ when placed at Θ inhabit the same shared space but, by balancing, possess their individual (and therefore summed on the scale-beam) magnitudes. Only two objects balance in space, not three, since the sphere and the cone form a single strange piece of art at Θ. This fact is not discussed and the text continues to operate mathematically as if two separate shapes occupy the same physical space at Θ, capable of individual manipulation and unique equalities on the scale-beam. In other words, the *Ephodos* operates as if the sphere and cone are shells, removable from one another, possessing only a shared center of weight. We might be led to think that we have imagined wrongly that the objects are solid; but no, the objects are to be imagined simply as solids in the sense of surfaces in mathematical space. These distinctions do not occur easily to the Greek reader, since Greek mathematics speaks *simpliciter* of geometrical objects as *magnitudes*, without reference to area, volume, or even physical

[56] Heiberg (1913: 441).

properties such as mass.[57] To summarize: multiple mathematical objects occupy the same space as one object; they have magnitude on the scale-beam and thus mass; they are solid; yet they are separable and treated individually. The discourse of physicalization of mathematical objects does not go very far in the *Ephodos*, acting more as a superficial veneer than substantive concretization. Archimedes says that they possess the physical properties of mass and centers of gravity, yet they are not limited by these qualities in the way real physical objects are.

The scale-beam is the second element of mechanical discourse in the *Ephodos*. As discussed above in 3.2.1, Archimedes had already used *a* mechanical method in *Quadrature of the Parabola*. The style of argumentation about the scale-beam is much different in *Ephodos* from that of the *Quadrature of the Parabola*.

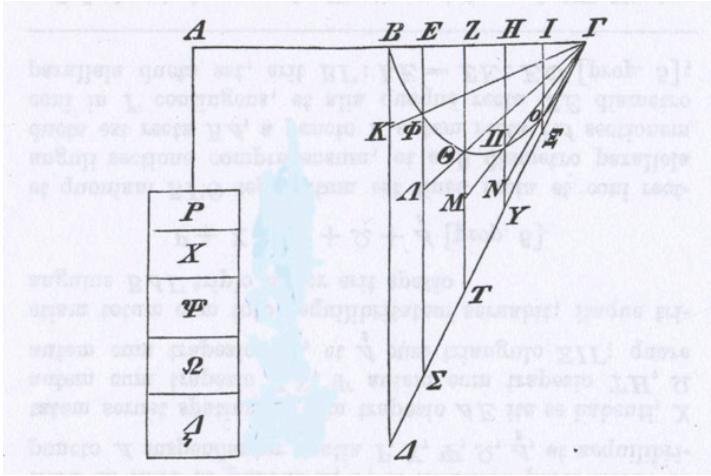

Illustration 9: Heiberg Diagram for *Quadrature of the Parabola* 14.[58]

While both treatises measure the area of a parabola upon the scale-beam, in *Ephodos* proposition 1 Archimedes guarantees that the center of weight of the triangle lies on the horizontal of the balance. Proposition 1 of the *Ephodos* differs from *Quadrature of the Parabola* 14, where Archimedes hangs the parabola by a terminal chord and locates the center of weight underneath the horizontal of the balance. Illustration 9 shows that in

[57] Netz et al. (2008: 45r1.3-13) *συμπληρωθέντος οὖν τοῦ κυλίνδρου καὶ τοῦ τμήματος τοῦ ὀρθογωνίου κωνοειδέ<ο>ς ἰσορροπήσει περὶ τὸ Α σημεῖον ὁ κύλινδρος αὐτοῦ μένων τῶ τμήματι τοῦ ὀρθογωνίου κωνοειδέος μετενεχθέντι καὶ τεθέντι τοῦ ζυγοῦ κατὰ τὸ Θ οὕτως, ὥστε κέντρον εἶναι αὐτοῦ τοῦ βάρους τὸ Θ. ἐπεὶ δὲ ἰσορροπεῖ περὶ τὸ Α σημεῖον τὰ εἰρημένα μεγέθη.*

[58] Heiberg (1913: 289).

Quadrature of the Parabola 14 the parabola BΘΓ hangs upon the scale-beam ABΓ. Triangle ΔBΓ (of which parabola BΘΓ is part) balances on the scale-beam against the combined weights P, X, Ψ, Ω, and Δ (these weights are respectively equal to the triangle ΞIΓ and trapezoids YI, TH, ΣZ, ΔE of triangle ΔBΓ). In *Quadrature of the Parabola* Archimedes does not ensure that objects are placed upon the scale-beam by their center of weight, as the fundamental theorem of the level demands: illustration 9 shows that triangle ΔBΓ, for instance, is not balanced on the scale-beam in its center of weight, where the diagonals of the triangle would intersect. In *Ephodos* Archimedes appears more concerned with adherence to the theoretical principle at stake: as illustration 10 shows, in *Ephodos* proposition 1 triangle ABΞ balances on its center of weight X where the diagonals of the triangle intersect.

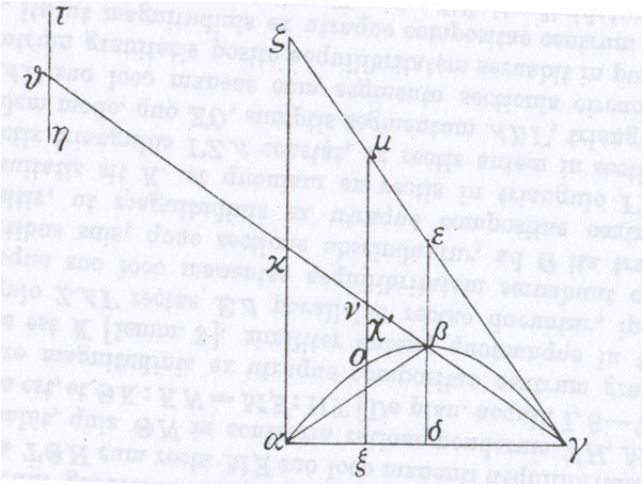

Illustration 10: Heiberg Diagram for *Ephodos* 1.[59]

The presentation of the scale-beam is quite different in each treatise. In *Quadrature of the Parabola* we look at the scale-beam as a plane perpendicular to the horizontal, as illustration 9 shows. Here we readers see each side of the scale-beam and can check that the beam ABΓ is balanced along the horizontal. The diagram encourages us to view the mechanical procedure primarily as a weighing procedure. Thus the diagram complements the text, where Archimedes places a sum of weights (P, X, Ψ, Ω,

[59] Heiberg (1913: 435).

and Δ) upon the scale-beam ΑΒΓ and weighs sum by sum the parabola ΒΘΓ hung inside the triangle ΔΒΓ.

In the *Ephodos*, on the other hand, we view the scale-beam from above the plane of the horizontal, looking down upon a flat plane. Illustration 10 shows the scale-beam ΘΚΓ balancing at its midpoint K in *Ephodos* proposition 1. The reader looks down at a horizontol plane from above: all the points in the plane appear at the same depth. From this perspective the reader is physically unable to view the fact that the scale-beam ΘΚΓ balances. The reader is forced to *assume* the balancing of objects on the scale-beam. Illustration 10 shows triangle ΑΓΞ balancing the line TH, as if a single line could balance a triangle.

Moreover, Heiberg's diagrams for the *Ephodos* are slightly wrong: in the manuscript the arbitrary line HT of *Ephodos* proposition 1 is drawn under the triangle ΑΒΓ, not at Θ as illustration 10 shows; in *Ephodos* propositions 6 and 9 no balancing object appears at Θ, one end of the scale-beam, although Heiberg drew a balancing object at Θ.[60] The act of placing a balancing figure at Θ that the text demands, even as slight a one as a single line, has no diagrammatic referent in the manuscript. In the absence of visual evidence the weighing procedure of the text exists only as a mental development in the mind of the reader. In addition to differences in the diagrammatic presentation of the scale-beam, the *Ephodos* does not weigh objects against solid weights, in the manner of the *Quadrature*. The discourse of the scale-beam in the *Ephodos* is purely conceptual and more tied to its theoretical principle rather than physical appearance.

What does Archimedes gain by drawing the *Ephodos* diagram so that the horizon has vanished? If the horizon is parallel to the ruling of the page as in *Quadrature of the Parabola*, the figures appear to hang suspended or affixed from the balance: as if a physical balancing was occurring. This might be our view of the process drawn from daily life, such as the measuring of purchases of grain by merchants; and inspecting the weighing procedure from the side of the balance is an effective attestation of the

[60] Heiberg (1913: 465, 479). I thank Reviel Netz for sharing his results with me about the shape of the manuscript diagrams from the palimpsest.

transparency and justice of the procedure for both the merchant and customer.[61] However, to view the weighing procedure from above at depth to a plane parallel to the ground as in the *Ephodos*, is to deny the observer the visual perspective to check the accuracy of the result. Objects placed at opposite ends of the balance will appear stationary when viewed from above, regardless of the balance or inbalance of those objects.

Archimedes' balancing the parabola on the scale-beam is a potentially performative scientific act, the spectacle of science. In chapter 1.3.1 I suggested that phenomena of scientific appropriation could be read either as *science* by an elite historical actor who understood the terminology of multiple sciences or as *performance* by a lay audience who did not understand cross-scientific appropriation. *Quadrature of the Parabola* invites the lay reader to picture the performance of weighing the parabola: the act of weighing is pictured from the side of its vertical plane so that the reader can check the accuracy of the scale-beam. *Ephodos*, conversely, purposely denies the interpretation of the performance of weighing. Since the scale-beam is pictured from above, the reader must assume that the balance of mathematical objects is correct. Furthermore, since the diagrams of the palimpsest show objects only on one side of the scale-beam, the diagrams show no act of weighing at all. The *Ephodos* as a scientific text precludes the reader from interpretating the measurement of geometric objects on the scale-beam as a performative act.

I argue that Archimedes sublimates the mechanical schematic of the scale-beam to the mathematical diagrammatic need. Archimedes draws the geometrical figures before he proceeds to weigh them; there is a narrative need to clarify sufficiently the relation of the geometric figures to each other. Further, as Netz (1999b) has argued, Greek mathematical texts underdefine their referents so that the reader must refer to the

[61] Cuomo (2001: 4-5) argues, following Lloyd (1990) (see chapter 1.2), that public presentation of numbers and numerical representations, regardless of the numeracy of the populace, is an attempt to present financial or political circumstances openly and transparently. Scholarly study of mathematical knowledge and numeracy among historical societies is now called ethnomathematics.

accompanying diagram for further topographic information.[62] Several points in the first proposition are underdefined by the text so that they must be further specified by the diagram; see below in 3.2.3. The development and use of the scale-beam, on the other hand, is intuitively clear from Archimedes' other work. In *Ephodos* mathematical diagrammatic referentiality is both narratologically and ontologically prior to mechanization.

The audience of Archimedes' *Ephodos* is therefore the narrow audience of elite Greek mathematicians. Mechanization is secondary to mathematics. Netz (1999b) has shown that the diagram chronologically preceded the text in a Greek mathematician's writing of a mathematical problem;[63] in the *Ephodos* that diagram denies the reader the spectacle of weighing. The ancient audience that understood the diagrams of the *Ephodos* was composed of practicing mathematicians, not mechanicians.

The third element of mechanical discourse is the center of weight. This concept is nowhere defined in Archimedes's works, but is defined by Pappus:

> λέγομεν δὲ κέντρον βάρους ἑκάστου σώματος εἶναι σημεῖόν τι κείμενον ἐντός, ἀφ' οὗ κατ' ἐπίνοιαν ἀρτηθὲν τὸ βάρος ἠρεμεῖ φερόμενον καὶ φυλάσσει τὴν ἐξ ἀρχῆς θέσιν
>
> I say that the center of weight of each body is some point lying inside [the body], from which the weight, once imagined hung, does not move if carried about and preserves its initial position.[64]

Archimedes too seems to operate with this sense of the term in several of his works. In the *Ephodos* he lists several axioms he has proved in *Planes in Equilibrium* and *On Conoids and Spheroids* before moving to the propositions, most concerned with how to operate with centers of weight as magnitudes and their location in circles and line

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[62] Netz (1999b: 178): "In short: a starting-point may be a diagram starting-point in a strong and weak sense. The weak sense is that the assertion would fail to compel had it not been for the diagram, even though the logical grounds for the assertion need not be related to the digram. The strong sense is that the content of the assertion is contained, non-verbally, in the diagram, and the written assertion is an unpacking of this information. In the weak sense diagram starting-points are ubiquitous, but less startling. In the strong sense they are less common, say one or two per prosposition on average (ranging from zero to a few)."

[63] Netz (1999b: 84).

[64] Pappus 8.5 (1030.11-13 Hultsch). Cited by Dijksterhuis (1987: 299).

segments.[65] It is clear that the center of weight has a complex relation to the perimeter of a solid object. It is only a point but has magnitude by the fundamental theorem of the scale-beam: centers of weight are inversely proportional to their distance from the fulcrum. The *Ephodos* speaks in two ways of the center of weight: first as a point, a location on the diagram, and second as a magnitude by the fundamental theorem of the scale-beam. A discourse about mechanics – a center of weight – is thereby transformed into the language of geometry.

Archimedes' treatment of τὰ μηχανικά in the *Ephodos* is therefore primarily conceptual and in no way involves physical experiments. Consider how Archimedes measures the parabola ΑΒΓ in *Ephodos* proposition 1: Archimedes' only supportive prop in τὰ μηχανικά is the scale-beam, ζυγός; his only protagonst is the very specific object he is measuring. We enter into the *tropos* with the specified object, the triangle ΑΓΖ, balanced at its center of weight (that is, we only know the conceptual balancing of the object on its proper theoretical point), at which moment all other necessary physical conditions of the act of balancing – the horizon, the inclination of the beam, the position of the fulcrum, the physicalization of the parabola – all disappear: our physical props and protagonists have become mathematical again. The result obtained from this process is also mathematical, namely that parabola ΑΒΓ is four-thirds the inscribed triangle.

3.2.3 Integrating the Mathematical and Mechanical: A Close Reading

In 3.1.2 I argued that Archimedes' mathematical practice in *Ephodos* proposition 1 is the paradigmatic *tropos* the *Ephodos'* opening letter recommends to Eratosthenes. Hence our best understanding of Archimedes' practice of integrating the mechanical into the mathematical will come from considering *Ephodos* proposition 1 in a detailed close reading. My close reading follows the order of the proposition.

A Greek mathematical proposition has a well-regulated structure traditionally in six parts, explained by Proclus in his commentary on Euclid's *Elements*: *protasis* or *enunciation*, which lists the general theorem to be proved; *ekthesis* or *setting-out*, which describes the particular instantiation of the general theorem; *diorismos* or *definition of*

[65] *Ephodos* 132-177.

goal, which asserts what holds in the particular case if the enunciation is true; *kataskeuē* or *construction*, which constructs the particular figure on which the particular case will be proved; *apodeixis* or *proof*, which proves the particular theorem on the particular figure; and *sumperasma* or *conclusion*, which restates the general enunciation and asserts that it has been proved.[66] I mark the distinct parts in the discussion by Roman numerals: I. *protasis*, II. *ekthesis*, III. *diorismos*, IV. *kataskeuē*, V. *apodeixis*, VI. *sumperasma*.

I. Archimedes launches proposition 1 directly with the *ekthesis* after the postulates, avoiding the *protasis* entirely. This is surprising, for it indicates that the *Ephodos* is not a mathematical treatise formalized in the usual manner. The first-horizon readers of Archimedes' *Ephodos* would therefore have expected that the *protasis* would precede the *ekthesis* and establish the general theorem to be proved, whereas the *ekthesis* sets out the specific mathematical figures to be used. The formal structure surprises the reader with an unexpected moment of specificity.

Now Archimedes has laid out the *protasis* to the first proposition in the introductory letter: "Therefore I first write what first became clear through mechanics, that any segment of a section of an orthogonal cone is four-thirds of a triangle which has the same base and an equal height."[67] Archimedes is not avoiding the constituent parts of a formal mathematical treatise, but he is violating their order; and by separating the *protasis* so far from its normal position, he highlights its absence from the proposition.

II. Archimedes begins the *ekthesis* by drawing the parabola ΑΒΓ and its diameter[68] ΔΒ, then extends the line segment ΔΒ to an under-specified point Ε.[69] The point Ε is under-defined in the text – it is beyond Β on the line ΔΒ – but will be sufficiently defined by diagram. "Belief in the authors' *word* is replaced by the inspection of 'figures'."[70] The ancient reader might first now unroll the scroll on the right and look to the diagram for guidance. Archimedes continually directs his readers' attention to conceptually important information in his paradigmatic first demonstration.

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[66] See Netz (1999a: 252-54).
[67] *Ephodos* 119-125.
[68] This would be called the axis of the parabola in modern terminology.
[69] The *ekthesis* covers *Ephodos* 191-198.
[70] Latour (1987: 47); see chapter 1.4.

First, Archimedes directs that ΔB be drawn parallel to the diameter of the parabola but, since Δ is the bisection of AΓ, the line segment through Δ and B *is* the diameter: the text orders a construction more general than the text itself gives. The text's seeming confusion relates to Netz's (2004a) arguments about the generality of naming conventions: Archimedes feigns ignorance of the specific diagram in order to enunciate a generalized proposition.[71] In *Quadrature of the Parabola* 1-4 Archimedes also bisects the arbitrary straight line bounding the parabola with the phrase ἡ ΒΔ παρὰ τὰν διάμετρον ἢ αὐτὰ διάμετρος "the straight line BΔ parallel to the diameter or the diameter itself", a phrase made formulaic by repetition so that by proposition 5 Archimedes drops ἢ αὐτὰ διάμετρος and refers to the specific diameter BΔ as if it were an arbitrary straight line segment παρὰ τὰν διάμετρον.[72] The conclusion of *Quadrature of Parabola* proposition 5 and its equivalent in *Ephodos* proposition 1 holds in the case of any arbitrary line drawn parallel to the diameter of the parabola.

The phrasing of the mathematics of generality in *Quadrature of the Parabola* and its continuance in the *Ephodos* has a narratological import. The text's move toward generality in *Ephodos* obscures the immediate placement of the parabola on the scale-beam, which has yet to be introduced. The text presented mechanical axioms before proposition 1: therefore we have been told to expect a mechanical demonstration as if the *Ephodos* is a mechanical treatise. We expect, from our knowledge of the application of mechanics to the parabola in *Planes in Equilibrium* or *Quadrature of the Parabola*, that Archimedes will place the parabola on the scale-beam so that its center of weight coincides with the line of the scale-beam. (The center of weight of the parabola lies on the diameter.) We might therefore expect that parabola ABΓ is to lie on a scale-beam, part of which is ΔB, with the point E serving as some as-yet-unspecified point on the horizontal of the scale-beam ΔBE. But we are not given the diameter; we are instead given ΔB. Archimedes diverts our attention from the place of the center of weight of the parabola, as if to downplay the possibility of a mechanical demonstration: the text

[71] Netz (2004a: 62).
[72] Netz (1999b: 127-167) argues that sheer repetition is the primary force that shapes the formulaic nature of the Greek mathematical lexicon.

seemingly precludes the possibility of mechanical performance; only mathematical readings are welcome.

Archimedes now joins at B the legs of the inscribed triangle ABΓ. He has now drawn the two figures of the enuciation, a circumscribed triangle and a parabolic section.

III. The *diorismos* makes explicit Archimedes' mathematical claim about the two figures, that the parabola ABΓ is four-thirds of the triangle ABΓ.[73]

IV. In the *kataskeuē* Archimedes constructs the remaining elements of the proposition.[74] He draws in legs of the external triangle ZAΓ from the tangent to the parabolic segment and a parallel to the diameter. He then constructs the scale-beam ("let be imagined <as> a balance the ΓΘ") by extending ΓB to Θ so that the fulcrum point K is a point on the boundary of triangle ZAΓ. But the story is not so simple as a construction. Although *νοεῖν* "imagine" is a regular verb in Greek mathematical writing, Netz (2009b) has pointed out that a change in gender of the articles of Greek mathematical objects regularly indicates a shift from their reality in the diagram to their imagined existence. Here the line ΓΘ becomes the scale-beam ΓΘ, a shift in gender from ἡ, the feminine article, to ὁ, the masculine article. We the readers, Netz (2009b) suggests, are invited to see ἡ ΓΘ, the <straight line> ΓΘ, *as* the scale-beam ὁ ΓΘ.[75] The shift from *seeing* to *seeing as* indicates how strongly Greek mathematicians feel the diagrammatic reality of the mathematical object. ΓΘ is not even introduced as a line, ἡ ΓΘ; rather the fact of its existence as a line is so taken for granted that Archimedes asks us only to "imagine" it as ὁ ΓΘ, the scale-beam. Archimedes has not so much constructed a scale-beam then but rather constructed purely mathematical objects; and when we work with the relations

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[73] The *diorismos* covers *Ephodos* 198-199.

[74] The *kataskeuē* covers *Ephodos* 199-207.

[75] Netz's (2009b) argument about imagination in Greek mathematics as a *seeing as* ought to be contrasted against some of his earlier remarks on imagination in Netz (2004a): "It seems that imagination is only required when it is necessary to furnish a full spatial object, participating in the geometric configuration. Imagination is a spatial, not a conceptual act" (2004a: 198); "B's polygon's only claim to existence seems to be the notice made in Step 3, of its *possibility*. One is tempted to say that to assert an object's possibility is tantamount to imagining its existence" (2004a: 95). It is often because Netz (2004a) sees Archimedes as a mathematical realist and literalist that he is tempted to make such fine-grained distinction in the *type* of imagining Archimedes enjoins; on the other hand, it is a strength of Netz (2009b) that Archimedes' work is compared to other types of mathematical imagination.

between objects we will deal with the existence of geometric realia, namely their metrical and topographic properties. The line ΓΘ has the metrical property that it is divided exactly in half so that KΘ equals ΓK; the scale-beam ΓΘ has the same metrical property and it has the mechanically-derived topographic property that it remains stationary. And because the scale-beam ΓΘ remains stationary at K, it cannot yet *be seen* to have anything balanced set upon it.[76]

What then is the point of *seeing* ἡ ΓΘ *as* the scale-beam ΓΘ? The text does not yet clarify it. Nothing has yet been proved; the *kataskeuē* merely provides the specific construction for the proof. At this point in the *kataskeuē* the scale-beam has a potential function, just as the geometrical object potentially has properties. Yet it would be equally wrong to argue that Archimedes' *kataskeuē* is only geometrical because the mechanical demonstration does not yet function: as if we were to say that, because Archimedes has not availed himself of the logically necessary properties of the parabolic segment ΑΒΓ, the geometrical argument is thus merely potential and is not geometrical at this point in the text too. We are supposed to *see* ΓΘ both *as* a line and a balance; the text directs our interest to the multiplicity of possibilities. The *kataskeuē*'s simple imperative *νοείσθω* thus invites a seeing-double from the reader: the geometrical interpretation remains while the mechanical interpretation is no longer precluded (as it was in the *ekthesis*).

Archimedes next selects a line ΜΞ in the triangle, parallel to the diameter of the parabola. This too is a move toward mathematical generality: any line in the triangle ΖΑΓ with the property that it is parallel to the diameter of the parabola would suffice for Archimedes' subsequent demonstration. That is to say, the line ΜΞ is an arbitrary (*τυχοῦσα*) line such that the subsequent procedure is repeatable with a different parallel line. Specifying the line ΜΞ is the final part of the *kataskeuē*: Archimedes has completed the figure drawn in the diagram of triangle ΑΒΓ, which is inscribed in parabola ΑΒΓ, which in turn is inscribed in triangle ΖΑΓ, whose side bisector ΚΓ has been doubled in length to Θ, all of which is a purely geometrical construction. There is the potential of a

[76] This is the primary reason, I suggest, why the diagram of the proposition presents no mechanical features: the diagram presents the proposition as it is at the end of the *kataskeuē*. If the *kataskeuē* had positioned the scale-beam such that it had something on one arm and was therefore out of balance, we should have expected a different diagram.

mechanical demonstration when the line ΓΘ is seen as a balance.

V. The *apodeixis*, signaled by ἐπεὶ οὖν, concludes several results immediately from the mathematics of the *kataskeuē*.[77] Since ΓΒΑ is a parabola, EB is equal to BΔ; Archimedes notes that this is proved in the *Conic Elements*, either Euclid's or Aristeaus'.[78] Likewise, all straight lines parallel to EΔ are bisected by ΚΓ: therefore MN is equal to NΞ and ZK equal to KA.[79] Now Archimedes has already proved in a geometric fashion in *Quadrature of the Parabola* 5 that the ratio of the parts of any line segment which extends from the ordinate to the tangent of the ordinate, when drawn parallel to the diameter of a parabola and so divided by the parabola, will be the same as the division that line segment occasions in the ordinate. Note then how a result from *Quadrature of the Parabola* stands as possible intertext here, although Archimedes does not in the slightest way allude to it. Within the span of three lines he has drawn two mathematical conclusions: the one from a previous mathematician's *Conic Elements*, the other from his own work *Quadrature of the Parabola*. Why then does he refer to the *Conic Elements* directly and *Quadrature of the Parabola* not at all? Neither theorem is a part of the cognitive reference kit mathematicians expect of their readers.[80] Archimedes downplays specifically the mathematical content of *Quadrature of the Parabola*. When *Quadrature of the Parabola* stands as intertext, it stands before all as an intertext for its mechanical procedure, not its results. Archimedes again limits the reader's interpretative possibilities by the authorial intent of intertextuality$_A$.

In the *apodeixis* of *Ephodos* proposition 1, the ordinate's parts ΑΞ to ΓΞ will have the same ratio as ΟΞ to ΜΟ.[81] By addition of equal ratios on either side, namely the remainder of the ordinate and the remainder of the line segment, we achieve ΓΑ to ΑΞ equals ΜΞ to ΜΟ. By the fact that line segments cut by parallel lines have equal ratios,

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[77] The *apodeixis* covers *Ephodos* 208-274.
[78] *Ephodos* 208-211. Archimedes is writing before the publication of Apollonius' *Conics*, which becomes the standard reference for conics the way Euclid's *Elements* becomes the standard elementary geometric text.
[79] *Ephodos* 211-214.
[80] In Netz's (1999b: 216-239) summary, Euclid's *Elements* is the *sine qua non* text that Greek mathematicians expect of their readers.
[81] *Ephodos* 215-220.

ΓA to AΞ equals ΓK to KN (by the parallel lines ZA and ΞM). Since ΓK is equivalent to KΘ, by more substitution we achieve ΓA to AΞ equals KΘ to KN and thus ΘK to KN equals MΞ to ΞO. Only the results of these steps are spelled out, since the procedures are probably too obvious for Archimedes' audience. In general the initial parts of the *apodeixis* are not very explicitly motivated and the development of mathematical thought is somewhat obscure.

By *Ephodos* line 221 Archimedes has established a complex relationship between a line segment of the bounding triangle ZAΓ, the MΞ, and a line segment of the parabola ABΓ, the ΞO. He has shown that the ratio of these two line segments is equal to the ratio of KΘ, which we recognize as one arm of the potential scale-beam, to KN. Archimedes now begins to speak explicity of centers of weight in the mechanical fashion. The pace of argument slows down, mathematical motivation becomes more explicit, and the proof moves inexorably to its conclusion. This is the heart of Archimedes' *tropos*.

Archimedes first notes that the point N is the center of weight of the line MΞ, by axiom 4, since its constituent halves are equal.[82] Notice how the discourse of the mechanical is suddenly foregrounded; for Archimedes could have said, MN is equivalent to NΞ, therefore the point N is the center of weight. But we have moved from seeing lines and parabolic segments and triangles to *seeing* them *as* weights and centers of weight. Archimedes continues in a mechanical manner by placing a copy of line segment ΞO at the far arm of the scale-beam so that it balances on its center of weight; therefore this copy, the HT, and MΞ balance by the fundamental theorem of the lever (the line segment joining their centers, the ΘN, is cut inversely proportional by the weights at either end). And if they are balanced weights, their center of weight is the fulcrum of the scale-beam, the point K. This balancing is a statement of ratios, ΘK to KN as MΞ to HT.

The motivation of arguing after the mechanical fashion now becomes apparent. The ratio of ΘK to KN as MΞ to HT is the same ratio as Archimedes had reached by line 221, MΞ to ΞO as KΘ to KN, for HT is equivalent to ΞO. Whereas we had earlier not seen the purpose of the complex ratio equivalence, we now see it as an individual claim

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[82] *Ephodos* 221-231.

about an arbitrary slice of the triangle ZAΓ balancing its contituent slice of the parabolic segment ABΓ when placed at points K and N. The text does not explain how these line segments relate to their respective geometric figures.

In fact no possible intertext of Archimedes' mechanical treatises could prepare us for this result or explain it. *Quadrature of the Parabola* balances whole geometric objects against each other. In illustration 9 from *Quadrature of the Parabola* 14 the rectangles P, X, Ψ, Ω, and Δ balance the triangle ΞΙΓ and trapezoids YI, TH, ΣZ, ΔE. Intuition about the physical world informs the understanding of balance in *Quadrature of the Parabola*: the experience of scale-beams in the market-place offers intuitive justification that the geometric representations of bar weights and sacks of grain, rectangles and trapezoids, balance each other. Yet what physical reality corresponds to the *Ephodos'* balancing of line segments? No mechanical intuition drawn from physical reality explains the balancing of an arbitrary slice of the triangle ZAΓ against its contituent slice of the parabolic segment ABΓ. The balancing of line segments in the *Ephodos* is abstraction beyond the physical world.

Archimedes now moves to perhaps the most innovative part of his *tropos*. Likewise, he says, however many lines in the triangle ZAΓ are drawn parallel to the arbitrary slice EΔ, they will be balanced by their constituent lines of the parabolic segment ABΓ when those lines are transferred and centered at Θ. And thus the center of all weights will be K, the fulcrum point of the scale-beam.[83] The text is not entirely clear: does it mean (1) that we can take any such arbitrary pair, a line segment from triangle ZAΓ and its constituent segment from parabolic segment ABΓ and balance them over K?[84] or (2) that we take all line segments in ZAΓ, as a group, and their constituent segments from parabolic segment ABΓ, as a group, and balance them together over K? That is, is this a sequential procedure, such as (1), or a procedure of sets, such as (2)?

The next sentence is key for solving this question. Archimedes concludes

> καὶ ἐπεὶ ἐκ μὲν τᾶν ἐν τῶι ZA<Γ> *τριγώνωι* <*τὸ* ZAΓ *τρίγωνον*> *συνέστακεν*, ἐκ δὲ *τᾶν ἐν τᾶι τομᾶι ὁμοίως τᾶι* ΟΞ *λαμβανομενᾶν συνέστακε τὸ* ΑΒΓ *τμᾶμα*, *ἰσορροπήσει ἄρα τὸ* ZAΓ *τρίγωνον αὐτοῦ μένον τῶι τμάματι τᾶς τομᾶς*

[83] *Ephodos* 233-242.

[84] Dijksterhuis (1987: 321-22) reads the text in this way.

τεθέντι περὶ κέντρον τοῦ βάρεος τὸ Θ κατὰ τὸ Κ σαμεῖον ὥστε τοῦ ἐξ ἀμφοτέρων κέντρον εἶμεν τοῦ βάρεος τὸ Κ.

> And since first the triangle ZAΓ has been composed of the <straight lines> in the triangle ZAΓ, and second the segment ABΓ has been composed of the <straight lines> taken in the segment similar to the <straight line> OΞ, therefore the triangle ZAΓ will balance and remain stationary at the point K by the segment of the section set around the center of the weight, the <point> Θ, so that the <point> K is the center of the weight of the <weight> of both.[85]

In the formulaic language of Greek mathematical language, ἐπεὶ … ἄρα, Archimedes makes an inference to reach his conclusion: since (ἐπεὶ) the triangle ZAΓ is composed of the line segments in ZAΓ and the parabolic segment ABΓ is composed of the line segments in ABΓ, therefore (ἄρα) the triangle ZAΓ balances the parabolic segment ABΓ at Θ.[86] It seems as if Archimedes has made a jump somehow from his earlier individual lines segments, the arbitrary slice of both the triangle and parabolic segment, to the whole geometric object. As the ἐπεὶ clause of the conclusion states, both geometrical objects are composed of their individual line segments. Archimedes makes a claim about how individual line segments stand, in a deep sense, for their geometric objects in the weighing procedure. This is the use of what are called indivisibles in modern scholarship, after its procedural use by Cavalieri in the 17th century.

If we construe the representation of line segments for their geometric objects as possibility (1) above, Archimedes' line of argument would imply that the reader must take each individual line segment from ZAΓ with its constituent part from ABΓ, weigh it so that they balance at K, and continue this procedure until he was persuaded inductively that all line segments of ZAΓ and ABΓ would satisfy the conditions of balance. Thus Archimedes would be making two types of inductive claims: first, that the triangle ZAΓ and parabolic segment ABΓ are made of line segments; and second, that the weighing procedure can be accomplished exhaustively to infinity by induction. Note how difficult it would be to establish an inductive chain of reasoning in the weighing procedure: as if there were some way of sequentially classifying all line segments in either geometric

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[85] *Ephodos* 243-253.

[86] See Netz (1999b: 138, 254-55) on the inference particle ἄρα and its place in the logical form of a Greek mathematical proof.

figure. Not only does this reading compel Archimedes to make multiple unsubstantianted claims, it also destroys the logical progression of the argument.

If, instead, we read Archimedes' representation of individual line segments for their geometric objects as possibility (2) above, the text presents us with only one inductive claim and lines 243-253 logically follow on lines 221-233 and 233-242. We are required to assume – it is nowhere stated – that a geometric figure is composed of its set of individual line segments. In lines 221-233 Archimedes proves that one member of the set of elements of individual line segments of ΖΑΓ and ΑΒΓ balance at K. In lines 233-242 Archimedes extends this result and argues that, since one element of the set balances, all elements of the set must balance. This is not an inductive proof but a property of their belonging to the set of elements of ΖΑΓ and ΑΒΓ. Finally in lines 243-253 Archimedes concludes that, since the set of elements of ΖΑΓ and ΑΒΓ balance at K, the geometric figures themselves balance at K. This reading has the advantage that it builds a single logical sequence of thought: from one element of a set, to all elements of the set, to the substitution of the object which stands for all elements of the set. Read in this way, the remaining mathematical question is how the triangle ΖΑΓ and the parabola ΑΒΓ are composed of the elements of line segments parallel to ΕΔ.

I argue that Archimedes takes the view that the line segments which compose the triangle ΖΑΓ and the parabola ΑΒΓ are elements of sets after axiom 11 in *Ephodos*.

> χρησόμεθα δὲ καὶ [ἐν <τῶι> προγεγραμμένωι κωνοειδῶν] τῶιδε τῶι θεωρήματι· αἱ κα ὁποσαοῦν μεγέθεα ἄλλοις μεγέθεσιν ἴσα τὸ πλῆθος κατὰ δύο τὸν αὐτὸν ἔχη<ι> λόγον τὰ ὁμοίως τεταγμένα, ἢ<ι> δὲ τὰ πρῶτα μεγέθεα <ποτὶ ἄλλα μεγέθεα> ἐν λόγοις ὁποιοισοῦν, ἢ τὰ πάντα ἢ τινα αὐτῶν, καὶ τὰ ὕστερα μεγέθεα ποτὶ τὰ ὁμόλογα ἐν τοῖς αὐτοῖς λόγοις ἢ<ι>, πάντα τὰ πρῶτα μεγέθεα ποτὶ πάντα τὰ λεγόμενα τὸν αὐτὸν ἕξει λόγον, ὃν ἔχει πάντα τὰ ὕστερον ποτὶ πάντα τὰ λεγόμενα.
>
> I employ also this theorem: if however many magnitudes equal in multitude to other magnitudes when ordered likewise two by two have the same ratio and the first magnitudes, either all or some of them, are to other magnitudes in however many ratios and the latter magnitudes are to the corresponding <magnitudes> in the same ratios, all the first magnitudes will have the same ratio to all the <magnitudes> being enunciated that all the latter magnitudes have to all the <magnitudes> being enunciated.[87]

[87] *Ephodos* 177-191.

In axiom 11 Archimedes appears to distinguish classes of enunciated magnitudes – the generic word for any kind of mathematical unit[88] – by their multitude. The argument about moving between elements of sets is an argument about increasing order of multitude, from points, to lines, to areas. Axiom 11 itself is a theorem about the preservation of proportion between elements of sets when the order of multitude of the set is increased, the very theorem we need to justify the above reading.

Netz, Saito, and Tschernetska (2001) have argued that axiom 11 is "based not on a simple assumption of indivisibles but on a very sophisticated argument in proportion theory."[89] As Netz, Saito, and Tschernetska explain, Archimedes' argument risks a logical fallacy concerning the axiom's extension to infinite sets. Triangle ZAΓ and parabola ABΓ are composed of the set of their respective line segments, but there are infinitely many members of this set. Archimedes proved axiom 11 in *Conoids and Spheroids* 1 but only under the condition of finite members of sets. How then can Archimedes intend his argument in axiom 11 to be valid for infinite sets in *Ephodos*? The answer is not clear and scholarship is divided, [90] but I will argue below in 3.3.1 that Archimedes' procedure satisfies the standards of repeatability and thus generality in the community of Greek mathematicians. At any rate, Archimedes has not argued in any way for the elementization of geometric figures into sets of lines; the analysis of ZAΓ and ABΓ into their constituent lines happen *simpliciter*, as if there was nothing unusual about it for Archimedes or his readers.

From this point in the *apodeixis* of *Ephodos* proposition 1 Archimedes' argument is conceptually much easier and the mathematical motivation very clear.[91] Archimedes first constructs the center of weight of triangle ZAΓ, the point X. By a result proved in *Equilibria*, this must be the point which divides a side-bisector of the triangle into a 3:1 ratio. And if the triangle ZAΓ balances the parabolic segment ABΓ when placed at Θ, then the distances of their respective centers of weight, ΘK and XK, must be in inverse

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[88] Mugler (1958: 280-82) *s.v.*

[89] Netz, Saito, and Tschernetska (2001: 21).

[90] Netz, Saito, and Tschernetska (2001: 17-19) lay out the main positions and offer a critique of each based on their reading of *Ephodos* 14.

[91] *Ephodos* 253-267.

ratio. Stated with substitution, ZAΓ is to ABΓ as 3:1. Further, since the triangle ZAΓ is fourfold of the triangle ABΓ, then by substitution triangle ABΓ is to parabolic segment ABΓ as 3:4. Thus the parabolic segment ABΓ is four-thirds of its interior triangle ABΓ.

VI. Here is the result we were promised in the *protasis* of the opening letter. But the proof ends without any restatement of the *protasis* above into generalized terms in the sixth traditional element of a Euclidean proof, the *sumperasma*: here a *sumperasma* might be *therefore any parabolic segment is four-thirds of its interior triangle*. The proof is concluded only in the specifics of parabola ABΓ to triangle ABΓ. The proof ends in specificity just as it began in the *ekthesis*.

3.2.4 A New Approach

The integration of mechanical and mathematical procedures and tools creates the emergence of a new mathematical approach that finds the areas of planar and solid figures, Archimedes' *tropos*. I will call Archimedes' *tropos* a 'scientific way of seeing.' Just as was argued in the case in Herophilus' pulse theory in chapter 2.3, the analysis of the emergence of new objects and approaches in science ought not to be located along the ideological axes of scientific realism and social constructivism. Rather, as ANT argues, scientific emergence depends on the networked structure of pre-existing science. Archimedes' *tropos* comes into being as a scientific way of seeing, whose existence is strengthened by the networked existence of the objects in the different ontologies of mechanics and mathematics and by ways of seeing in those separate ontologies.

First, the objects that *Ephodos* proposition 1 considers are mechanical only in one respect. The property of centers of weight is the only mechanical property mathematical objects possess in the *tropos*' way of seeing: solid mathematical objects can occupy the same position in mathematical space although solid physical objects cannot, as was argued in 3.2.2; the mathematical objects, a line segment and a line segment, weighed against each other on the scale-beam balance as mathematical objects, although no physical intuition makes sense of this procedure, as was argued in 3.2.3. The *tropos* considers only the physical property of centers of weight.

Furthermore, the text strongly invokes the mathematical potential of mechanical objects. The *apodeixis* of *Ephodos* proposition 1 depends on tools which preserve mathematical proportions: the scale-beam and the indivisibles argument. The indivisibles preserve proportion when sets increase in multitude, as was argued in the *apodeixis* of 3.2.3; the scale-beam preserves geometrical proportions. Balancing is thus a mathematical act, not a physical one, as was argued in 3.2.2: there is no physical or mechanical spectacle in the *Ephodos*' *tropos*.

Archimedes directs the reader's attention to the mathematical aspects at all but one point in *Ephodos* proposition 1. The *kataskeuē* of *Ephodos* proposition 1 is the only formal section of the argument where Archimedes does not limit the reader's interpretative possibilities of a mechanical demonstration. The *ekthesis* limited the possibility of a mechanical demonstration when Archimedes directed that ΔB be drawn parallel to the diameter of the parabola. The *apodeixis* limited the possibilities for mechanical demonstration by alluding to textual codes of mechanization drawn from *Quadrature of the Parabola* as an intertext for its mechanical method. As the summary of Latour (1987) in chapter 1.4 showed, a scientific paper is continually trying to drive a single interpretation upon its reader. The reader *sees* the mathematical *as* mathematical; the reader also *sees* the mechanical foremost *as* mathematical. Only the *kataskeuē*'s imperative to *see* the line ΓΘ *as* a scale-beam invokes the mechanical property of the centers of weight of the constructed figures.

Archimedes' *Ephodos* pushes the mathematical reader toward a new approach, the integration of the mathematical 'way of seeing' mechanical objects into a mathematical analysis of linear sets which comprise geometric figures. Archimedes exerts authorial control through intertextuality$_A$: the text alludes to expectations of the cultural codes of mechanized mathematics while deliberately passing over in silence any direct allusions to *Quadrature of the Parabola*. The *tropos* emerges from the selective integration of mechanical properties into mathematical imagination. Archimedes' *tropos* in the *Ephodos* thus emerges from a networked structure of the mathematical reader's knowledge of the formal structure of proof in Greek mathematics; the textual codes of physical mechanization; the law of the lever and the mathematical consequences of the

balanced scale-beam; the mathematical assumption that individual line segments compose their geometric objects as members of sets; and all the numerous unmarked mathematical tools of diagrams, manipulation of ratios and proportions, ellipsis of technical formulae, and so on.

3.3 THE REJECTION OF IDEOLOGICAL CONSEQUENCES

3.3.1 Generality in Greek Mathematics

A recurring theme in my reading of *Ephodos* proposition 1 is Archimedes' aversion to certain formalist features in lieu of specific ones, while he is at the same time attempting to establish a repeatable and invariant pattern of argument in the mechanical process. Mueller (1981) has questioned the conditions by which Greek mathematicians tacitly argue for the generality of their conclusions. He argues his case on the basis of Euclid's *Elements*, which is to be taken as the normative style of ancient Greek mathematics. His arguments are worth considering in detail, especially because they highlight the formalist aspects of the Euclidean style.

> In Euclid's proofs of theorems the transition from the end of the *apodeixis* to the *sumperasma* looks very much like a compressed representation of this kind of inference [Hilbert's abstract claim that certain relationships hold given properties of a certain kind, e.g. $\forall A \forall C\ (A \neq C \rightarrow \exists D\ \ni A$ is between D and $C) \mid A, C, D$ are points] in which one moves directly from the conclusion based on the *ekthesis* to the fully universalized proposition which has been proved. The step of conditionalization is so natural that it is difficult to know whether or not to count it as an inference of which the Greeks were conscious. The evidence from their logical writings suggests that they did not grasp very clearly the difference between an inference and a conditional proposition … Thus in a Euclidean proposition what is proved is stated three times, first generally in the *protasis*, then in terms of a particular example in the *ekthesis-diorismos*, and then in the summary in the *sumperasma*.[92] The explanation for this logical redundancy would seem to be connected with the difficulty of grasping the idea of generalization … It is natural to ask about the legitimacy of such a proof. How can one move from an argument based upon a particular example to a general conclusion, from an argument about the straight line *AB* to a conclusion about any

[92] Netz (1999b: 253): "The first thing worthy of notice is that Mueller is very untypically wrong [here]. He asserts that the *demonstrandum* is repeated three times in different forms; he also asserts that 'the *sumperasma* repeats what was insisted upon in the *diorismos*.' In fact, the *demonstrandum* is repeated *four* times, and the *sumperasma* repeats the *protasis*, not the *diorismos*."

> straight line? I do not believe that the Greeks ever answered this question satisfactorily, but I suspect that the threefold repetition of what is to be proved reflects a sense of the complexity of the question. The *prostasis* formulated without letters to make the generality of what is being proved apparent. The *ekthesis* starts the proof, but, before the proof is continued, the *diorismos* insists that it is only necessary to establish something particular to establish the *protasis*. When the particular thing has been established, the *sumperasma* repeats what was insisted upon in the *diorismos*. Of course, insisting that the particular argument is sufficient to establish the general *protasis* is not a justification, but it does amount to laying down a rule of mathematical proof: to prove a particular case is to count as proving a general proposition … The statement of the logical rule involved includes a precise specification of the conditions under which generalization is permitted. Although these conditions are stated formalistically, they have a justification which makes clear that universal generalization is permitted only when no special assumptions have been made about the particulars in terms of which the proof was carried on. In the case of Hilbert's theorem 3, the permissibility of such generalization is made clear by the fact that the conditional to which generalization is applied depends upon no assumptions in which the letters *A* and *C* occur as "free" variables. Since no such assumptions are made, there is a sense in which *A* and *C* are not particular points at all … Thus logic and the structural interpretation of mathematics make it possible to give a clear and reasonable account of ordinary mathematical reasoning. However, there is no reason to suppose the Greeks to have had anything like modern logic to represent actual mathematical argument, and the Euclidean style makes it look as though a proof is thought of as being carried out with respect to a particular object, but in a way assumed to be generalizable. In the absence of something like the rules of logic there is no uniform procedure for checking the correctness of this assumption in individual cases. Rather one must rely on general mathematical intelligence.[93]

Mueller argues that Greek mathematicians improperly claim to have proved a generalized result (e.g. that any parabola is four-thirds of its inscribed triangle) but, in fact, they have only proved a specific result (e.g. that parabola ΑΒΓ is four-thirds of the inscribed triangle ΑΒΓ). Mueller's argument does more to establish a modern critique of the particularism of Greek mathematics than explain it. Certainly from the modern perspective, Greek geometry cannot claim a general result without recourse to broader definitions of elements, sets, and classes. Mueller's explanation for the Greek mathematicians' false claim of generality is more or less the ritualized structure of the Euclidean style proof according to Proclus' classification of *protasis*, *ekthesis*, *diorismos*,

[93] Mueller (1981: 12-14).

kataskeuē, apodeixis, *sumperasma*: Greek geometers accept general claims for the proof because they repeat the *demonstrandum* in a structured way.[94]

Netz (1999b) has the best response to Mueller likely to be offered for a while.[95] At issue, Netz thinks, is not the logic of generalization of Greek mathematics but the social willingness of ancient Greek mathematicians to be satisfied with the results of Euclidean style. To Netz, this must be a cognitive claim about the shared practices of Hellenistic Greek mathematicians. Netz argues that the cognitive practices his book identifies – a formulaic lexicon and diagrammatic conventionality – make the cognitive edifice of the proof repeatable and invariable and so necessitate that the mathematicians check only their proper application.[96] (In the language of this study drawn from the summary of Latour (1987) in chapter 1.4, Greek mathematics is a networked structure whose intellectual archaeology is identifiable for any given problem.[97]) In essence then, Netz's theory is that Greek mathematics is linguistically performative on a specific object: the mathematician asserts and persuades his readers that certain things obtain on the diagram at hand. The current proof can be re-done by another later mathematician; the present mathematican can redo the previously-proved theorems on which his current proof is dependent. The implicit suggestion is that if a theorem obtains for triangle ΑΒΓ it will obtain for triangle ΔΕΖ and triangle ΗΘΙ and so on. Netz argues that because the

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[94] Mueller (1981) is willing to ascribe generality as the *intention* of Greek mathematicians even when they fail to use this ritualistic structure. In his discussion of the arithmetic books of the *Elements*, 7-9, he notes (1981: 68) the usual absence of a *sumperasma*: "There would be not seem to be any philosophical or mathematical reason for its absence since Euclid's arithmetic proofs are as general as his others. The problem of generality is, however, much more explicit in the arithmetic books." The formal structure of proof in the arithmetic books of the *Elements* is thus identical with the formal structure used in in *Ephodos*. Mueller nonetheless argues that generality does not obtain in the arithmetic books of the *Elements* on other grounds than the absence of the *sumperasma*.

[95] Netz (1999b: 240-270).

[96] I offer a metaphorical description to illustrate Netz's theory: a Greek mathematician trusts that another mathematician's bricks and mortar will fasten and that his schematics are sufficiently illustrative; the Greek mathematician believes that structural integrity results from the proper use of these tools.

[97] The scientific dissenter who wishes to dissect and un-tie the chain of associated proofs in Greek mathematics finds blackboxes of results readily identifiable through the networked structure which mathematics formalizes in proof: at the bottom, of course, the dissenter reaches down to Euclid's *Elements*. Latour (1987: 92): "The point is that the new object emerges from a complex set-up of sedimented elements each of which has been a new object at some point in time and space. The genealogy and the archaeology of this sedimented past is always possible in theory but becomes more and more difficult as time goes by and the number of elements mustered increases."

entire sequence is not laid out, argument in Greek mathematics is different from mathematical induction; rather, Greek mathematics is deductive. The theorem obtains in other triangles because the proof is repeatable. In this way Greek mathematics is a chain of specific performative moments, some part of which the community of professional mathematicians accepts as sufficiently proven to need no further instantiation.

What we gain from Netz's answer to Mueller is the insight that the interplay of repeatable procedures on specific objects to necessitate a general conclusion is a characteristic of normative Greek mathematical style. But the first proposition of the *Ephodos* lacks an integrated *protasis* and entirely lacks a *sumperasma*. If we accepted Mueller's arguments about the conditions by which Greek mathematics achieve the generality of their conclusions, Archimedes could not claim that the argument was valid. For Mueller *Ephodos* 1 cannot achieve generality since the proposition lacks the ritualized structure of by which mathematical generalization is obtained: *Ephodos* proposition 1 lacks a *sumperasma*.[98] What is at stake in *Ephodos* proposition 1 is something different than assuring the generality of the mathematical argument about the parabolic segment ΑΒΓ and the triangle ΑΒΓ, that is to say, different from a proof of the generality of the enuciation that a parabolic segment is four-thirds of its inscribed triangle. Archimedes seems not particularly interested in the generality of that enunciation but rather in the generality of his *tropos*, a results-oriented mechanical argument about the sets of indivisibles composing two geometric objects.

I argue therefore that Archimedes aims to give an innovative methodic procedure that satisfies Greek mathematicians' expectations about logical necessity and mathematical generalization. We must accept the following conditions: that objects are analyzable as sets of elements; that a mechanical route is available to the imagination of the reader; that the text underdefines topographical qualities of mathematical necessity; that mathematical diagrammatic referentiality takes precedence to the mechanical. The mechanical argument is then executed in the mind of the reader, without visual

[98] A case can be made, however, that Mueller would be willing to grant Archimedes' intention of having a generalized proof, even if Mueller would deny that generality obtains because of the lack of specification of the conditions of generality. See footnote 94 above.

accompaniment. Mathematical necessity is grounded in the repeatability of the solution to the proposition starting from different specific objects, in accord with Netz's response to Mueller.

3.3.2 Formalism in Archimedes' Introductory Letter

If, therefore, Archimedes has successively produced a methodic *tropos* that satisfies Hellenistic mathematicians' demands of mathematical necessity and generalization, we should expect that Archimedes employs the principles demonstrated in proposition 1 through the rest of the *Ephodos*. I have argued above in 3.1.2 that this is the case. But to what end has Archimedes devised the *tropos*' methodic connection between *τὰ μαθήματα* and *τὰ μηχανικά*? Since the close reading of the proposition only makes clear Archimedes' implicit practice, we must return to the opening letter of the *Ephodos* for Archimedes' explicit observation on its use.

The introductory letter of the *Ephodos* identifies a formal division between the mechanical way, in which things are seen or contemplated (*θεωρεῖν*, *φαίνεσθαι*), and the geometrical manner, in which things are proved (*ἀποδεικνύναι*, *ἐπιδείκνυναι*). Two papers independently argue that Archimedes intends to show a chronological development of discovery and proof. Cambiano (1992) points out that in *Quadrature of the Parabola* the contrast between discovery and proof is between the matrix of *εὑρίσκειν* / *θεωρεῖν*, always in the aorist, and *ἐπιδεικνύναι* / *ἀποδεικνύναι*, always in the present tense. The implication of the verbal similarities of *Ephodos* and *Quadrature of the Parabola* between discovery and proof, he argues, is that discovery precedes proof via the mechanical method, so that the difference between the mathematical method and the mechanical method is primarily one of veridical value of a similar process.[99] Knobloch (2000) also constructs a verbal matrix from the *Ephodos* of *εὕρεσις*, *ἀπόφασις*, *ἀπόδειξις*.[100] Apodeitic proof, he argues, proceeds by analogy to the mechanical method, that is, from the triple of "action, operator, and result" whose parts are *θεωρεῖν*, *θεωρία*, *θεωρῆμα*.[101]

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[99] Cambiano (1992: 22-23).
[100] Knobloch (2000: 84).
[101] Knobloch (2000: 92).

Now Cambiano's (1992) and Knobloch's (2000) claim that discovery proceeds proof in chronological sequence is undoubtedly true according to the opening letter. As Archimedes presents it, the mechanical way offers a certain understanding (γνῶσις) of the problem at hand, so that it is easier to proceed in the formal proof. Historical evidence shows this is the case: Democritus claimed certain results and Eudoxus proved them.[102] Cambiano (1992) argues that Archimedes' description of the move from Democritus' declaration of discovery (ἀποφηναμένωι) to Eudoxus' proof (ἐξηύρηκεν) presages Archimedes' own chronological move from discovery to proof.[103] Without access to the palimpsest, Cambiano (1992) simply follows Heiberg's (1913) reading of ἐξηύρηκεν, a word usually indicating "discovery of a solution". Cambiano's (1992) case is improved with Netz et al.'s (2008) reading of ἐξήνεγκε, a word more in line with Cambiano's (1992) intended sense of "publication of a proof".

Concern to uncover the development of Archimedes' thought drives the readings of Knobloch (2000) and Cambiano (1992). Both publications concern themselves almost exclusively with Archimedes' explicit claim about the use of his *tropos*. This style of reading, when extended to include the propositions, will seek to expand on the observed distinction between the mathematical and mechanical and will aim to determine the

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[102] Knorr (1996: 74) cites the introductory letter in *Sphere and Cylinder* 1 (Heiberg 1910: 4.2-13) and takes this fact to be indicative of developments in the chronology of Archimedes' writings. But Netz (2004a: 34), in comparing the same passage, Archimedes' only other historical review, sees not a historical development but a literary strategy: "The comparison is worrying in two ways. First, the *Method* passage concerns, once again, the same relation between cone and cylinder, i.e. it seems as if Archimedes kept recycling the same story. Second, the *Method* version seems to contradict this passage (*SC* [i.e. *On the Sphere and Cylinder*]: no knowledge prior to Eudoxus. *Method*: no proof prior to Eudoxus, however already known to Democritus.) Was Archimedes an old gossip then? A liar? More to the point: we see Archimedes constantly comparing himself to Eudoxus, arguing for his own superiority over him. This is the best proof we have of Eudoxus' greatness. And as for the facts, Archimedes was no historian." Knobloch (2000: 85-7) goes in a different direction, arguing that Democritus was concerned with physical and not mathematical practicalities; he sums up, "Apparently, Democritus and Archimedes are representative of two types of reasoning: of physical and non-rigorous reasoning on the one hand and of mathematical reasoning on the other."

[103] Cambiano (1992: 23) "Qui la distanza cronologica tra i due autori è inequivocabile e corrisponde a un'antecedenza della'ἀποφαίνειν privo di dimonstrazione, assimiliable a momento della scoperta, rispetto alla dimostrazione data da Eudosso. Che anche nel caso di Archimede la scoperta sia presentata da lui come cronologicamente anteriore alla dimonstrazione mi pare confermato dalle parole conclusive della premessa, quando dice γράφομεν οὖν πρῶτον τὸ καὶ πρῶτον φανὲν διὰ τῶν μηχανικῶν. Se il primero πρῶτον riguarda l'ordine espositivo, il secondo sottolinea la priorità cronologica della scoperta. Il problema che allora si pone è quello della relazione tra i due momenti cronologicamente distinti della scoperta e della dimonstrazione."

Ephodos's pivot point between the mathematical and mechanical, as if to determine Archimedes' developmental priority of one mode of mathematics. But a reading which seeks to divide the mechanical and mathematical is ultimately mistaken. Archimedes' explicit claims in the opening letter about his innovative connection between the mathematical and mechanical precludes reading the text with the sole purpose of distinguishing them. As we have seen in the close reading of *Ephodos* proposition 1 in 3.2.3, Archimedes' *tropos* is a selective integration of the mechanical into the mathematical.

In his opening letter Archimedes claims that his methodic *tropos* provides ἀφορμαί, starting points, for seeing things in the formal proof of mathematics. What these might be are not clear: is it (1) simply the result of the argumentation? or (2) the mathematical *kataskeuē* required for the indivisibles argument? or something else? In the absence of direct evidence from *Ephodos*, our best evidence is comparative: Archimedes has already given a formal proof of the area of the parabolic segment in propositions 18-24 of *Quadrature of the Parabola*. We therefore proceed with an analysis of this formal mathematical proof.

Archimedes begins his proof that the area of a parabola is four-thirds its inscribed triangle in his usual, indirect fashion. He establishes in proposition 18 that the diameter of a parabolic segment is the longest perpendicular in the segment; he establishes in proposition 19 an important result that, based on a result from proposition 3, the diameter of a parabolic segment is four-thirds the diameter of a half-segment. Proposition 20 establishes an inequality between half of the parabolic segment and the entire segment's inscribed triangle. Archimedes can use the procedure of *Elements* 10.1 to make the inequality ever-smaller, tending toward equality. Proposition 21 establishes that, once the large triangle is inscribed in the segment, triangles inscribed in the area remaining inside the segment are one-eighth of the large triangle; further inscribed triangles, had Archimedes drawn them, would be one-eighth of their respective triangles, thus creating a geometric series of progressively smaller triangles. Proposition 22 again creates an inequality condition building on the results of propositions 20 and 21: the summed sequence of inscribed triangles is shown to be less than the whole segment. Proposition

23 is a result from proportion theory, showing that the sum of a certain geometric series (the geometric series described in proposition 21) is four-thirds of its largest member.

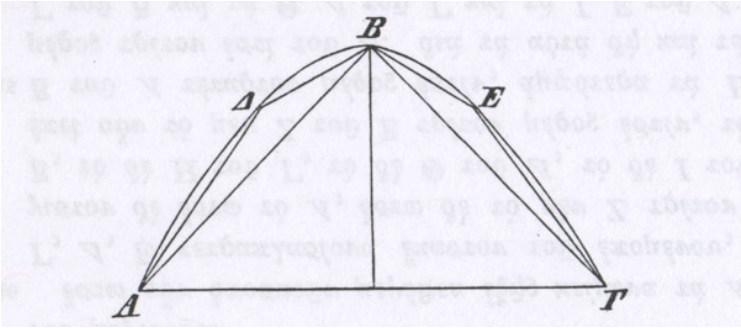

Illustration 11: Heiberg's Diagram for *Quadrature of the Parabola* 24.[104]

Finally, in proposition 24 Archimedes triggers the inequality condition as shown in illustration 11: the sum of the geometric series of inscribed triangles starting with AΔB, BEΓ, and ABΓ and approaching ever closer to the parabolic curve is shown to fail to be greater than the hypothesized area of the parabolic segment ABΓ and shown to fail to be less than that area; therefore it must be equal, four-thirds of the inscribed triangle ABΓ.

Archimedes formally resolves the proof by a *reductio ad absurdum*, although Archimedes' use of a summed series of inscribed figures which yields an inequality condition trending toward equality is often called the method of exhaustion.[105] The *reductio*, for all its celebrated strength,[106] is a very indirect logical claim: it rejects the correctness of any other possible answer.[107] The typical *reductio ad absurdum* argument therefore begins with its conclusion in mind. Note that in *Quadrature of the Parabola*

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[104] Heiberg (1913: 312).

[105] Dijksterhuis (1987: 130) is critical of this name: "We will characterize briefly rather than correctly by the expression 'indirect passage to the limit'. We will avoid the widely used term 'exhaustion method'; for a mode of reasoning which has arisen from the conception of inexhaustibility of the infinite, this is about the worst name that could have been devised." The method of exhaustion receives its name from the successive application of areas ever nearer the full area of a given figure. *Elements* 12.2 demonstrates the technique: that a circle's area is relative to given rectilinear area is shown by the ratio of the area of successive polygons inscribed in the circle. Strikingly *Elements* 12.2 is proved with only an inscribed polygon, not a circumscribed one. Knorr (1986: 79) argues that one-sided exhaustion (in his words, "convergence") is a characteristic of the older Eudoxean method.

[106] Hardy's (2000: 94) metaphor is famous: "[*Reductio ad absurdum*] is one of the mathematician's finest weapons. It is a far finer gambit than any chess gambit: a chess player may offer the sacrifice of a pawn or a piece, but the mathematician offers *the game*." Emphasis in the original.

[107] Indeed, this must be the case whatever the number of truth values, whether a two-valued or a three-valued or multi-valued logic.

18-24 Archimedes argues with the conclusion in mind – that the parabolic segment is four-thirds of its inscribed triangle – but that no algorithm determined in what way that conclusion could be applied. Archimedes could have inscribed trapezia, as in *Quadrature of the Parabola* 6-17, instead of triangles; he could have used circumscribed figures instead of inscribed figures; he could have used both inscribed and circumscribed figures as in *Spiral Lines* 18. The *reductio ad absurdum* is a logical technique but not an algorithmic one because it in no way determines the methodological character or form of the mathematical argument.

Yet what better starting point could there be for a *reductio ad absurdum* argument than the theorem's result? In fact, that initial starting point (*ἀφορμή*) is the only thing Archimedes promises of *Ephodos* proposition 1 and needs for the formal proof of *Quadrature of the Parabola* 18-24. The result alone, I argue, is the obvious candidate to satisfy Archimedes' claim *τοῦτο δὲ πέπ<ε>ισμαι χρήσιμον εἶμεν οὐδὲν ἧσσον <ἢ> καὶ εἰς τὰν ἀπόδειξιν αὐτῶν τῶν θεωρημάτων* "This, I am persuaded, is useful for nothing less than for the proof of the theorems themselves."[108] Archimedes claims his *tropos* aids in apodeictic proof, the formal mathematical demonstration.

3.3.3 Traditional Formalism, or The Rejection of Innovative Practice

We should not posit a divide between Archimedes' claims in the opening letter of the *Ephodos* and his practices in the propositions without due cause. In this case, there is good reason to see a divide between the types of methodological commitments offered in the proposition and the opening letter. In *Ephodos* proposition 1, Archimedes practices mathematical argument according to Greek standards of proof in a generalizable and repeatable way: its re-performativity assures its methodic self-reflection in the normative manner of Greek mathematical argumentation. In the opening letter, Archimedes claims that his *tropos* offers starting points and the ability to contemplate mathematical things, a very limited claim about his formal accomplishment in his science. So Archimedes offers more "good mathematics" in his practice than his claims. Now Archimedes is

[108] *Ephodos* 80-83.

hardly shy in his other works – or even in *Ephodos*[109] – about claiming the primacy of his achievement. Therefore, we should expect him to claim honors for his accomplishment in a new methodic approach to mathematics.

There is an unexpected gap then between Archimedes' claims in the opening letter about his scientific achievement and his accomplishments in practice in the propositions. That Archimedes does not boast of the primacy of his achievement for his methodic accomplishment indicates something else is happening here. As Archimedes intimates in the opening letter, a sequential move from mechanical method to geometrical method, Cambiano's (1992) chronological and Knobloch's (2000) analogical development, is a movement toward communally accepted forms of rigor. Traditional community standards of argumentation ultimately supersede innovative science.

The meta-mathematical observation after the first proposition further explains the primacy of formal mathematical argumentation.

> [T]*τοῦτο δὴ διὰ μὲν τῶν νῦν εἰρημένων οὐκ ἀποδέδεικται, ἔμφασιν δέ τινα πεποίηκε τὸ συμπέρασμα ἀληθὲς εἶμεν· διόπερ ἀμὲς ὁρῶντες μὲν οὐκ ἀποδεδειγμένον, ὑπονοέοντες δὲ τὸ συμπέρασμα ἀληθὲς εἶμεν, <ἐ>τάξομες τὰν γεωμετρεομέναν ἀπόδειξιν ἐξευρόντες αὐτοὶ τὰν ἐ<κ>δοθεῖσαν πρότερον.*
>
> So this was not proven by what was now said but still creates a certain impression that the conclusion is true. Wherefore I, seeing that <the conclusion> is not proven but nonetheless suspecting that the conclusion is true, will test [it] in respect to the geometrized proof, which was published earlier after I myself discovered it.[110]

This is not the usual text or translation of this passage. Heiberg (1913) offers "demonstrationem per geometriam a nobis ipsis inuentam suo loco proponemus, quam eandem antea edidimus," taking *τάξομεν* in an extended sense of "order", "arrange in its proper place".[111] He appends a note arguing that Archimedes placed this proof at the end of the book.[112] Dijksterhuis (1987) too translates "we shall mention the previously published geometrical proof, which we ourselves have found for it, in its appointed

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[109] See *Ephodos* 57-65, Archimedes' boast about his successful comparison with conic sections with rectilinear and planar figures.
[110] *Ephodos* 276-85.
[111] Heiberg (1913: 439).
[112] Heiberg (1913: 439n.4).

place," and goes beyond Heiberg to suggest that Archimedes published regular proofs of all propositions covered in the *Ephodos* at the end of the book.[113] Indeed, the number of times Archimedes makes references to his own previous work in the *Ephodos* is remarkable. But it seems very unlikely that, as proud as Archimedes is of his result on parabolic quadrature, he would repeat the proof again. And if Heiberg's suggestion is too much, the view of Dijksterhuis is simply fantastic.[114]

The problem, then, is that commentators have expected Archimedes to resume talking about the geometrical proofs but no common sense solution allows Archimedes the space necessary at the end of the treatise for the full geometrical proof. Following Arendt (1914), I suggest that what is at issue is still Archimedes' *tropos*. Therefore I diagnostically conjecture <ἐ>*τάξομες*, the Doric future of ἐτάζειν.[115] The change has the advantage of continuing the text's focus on the methodic *tropos* following the reading of proposition 1 as a manner of proof.

Despite its appearance – *συμπέρασμα* "conclusion", *ἀπόδειξις* "proof" – the passage is not full of technical mathematical vocabulary. In fact, *συμπέρασμα* "conclusion" here cannot have the sense of the final repetition of the generalized result in the Euclidean-style, because there was no *συμπέρασμα* in the text of the first proposition. Rather, *συμπέρασμα* must have a logical sense, simply the result of an argument. The text therefore concerns the comparison of a result of the *tropos* to formal result. It is a shift in category and to claim one formal result in another forum is a category error. Archimedes prefers the interpretative category of formal mathematics, *τὰ μαθήματα*, as the final arbiter of the correctness of proof.

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[113] Dijksterhuis (1987: 318).

[114] Arendt (1914: 293), following on his remark (see Appendix B footnote 45) about the unexpected plurals of *Ephodos* 83-87 *καὶ γὰρ <τινα τῶν> πρότερον μοι φανέντων μηχανικῶς ὕστερον γεωμετρικῶς ἀπεδείχθη διὰ τὸ χωρὶς ἀποδείξιος εἶμεν τὰν διὰ τοῦ τρόπου θεωρίαν*: "Es wäre ferner sehr merkwürdig, wenn Archimedes in dieser Schrift eine ganze Anzahl von bisher unbekannten oder doch unbewiesenen Sätzen durch die mechanische Methode herleitete, aber nur für die beiden unter ihnen, die von den den Mathematikern seiner Zeit geläufigen Sätzen am weitesten ablagen (die Sätze über den Zynlinderhuf und die beiden sich durchdringenden Zylinder) außerdem den exakten Beweis gäbe; daß er gerade disese beiden Sätzen früher an Eratosthenes gesandt hat, wäre doch schwerlich ein hinreicheneder Grund. Dagagen wird alles klar, wenn eben diese beiden Sätze die einzigen von allen in der Schrift erwähnten waren, für die der exakte Beweis noch ausstand."

[115] See Appendix B for a discussion of the intent of a diagnostic conjecture.

Now this introduces a strange paradox. For in spite of his claims for its heuristic power, Archimedes denies the formal demonstrative power of the mechanical method: [T]*τοῦτο δὴ διὰ μὲν τῶν νῦν εἰρημένων οὐκ ἀποδέδεικται* "So this was not proven by what was now said."[116] Scholars have debated what Archimedes objects to: Knorr (1996) suggests that it was the use of physical considerations; Dijksterhuis (1987) maintains that it was the use of indivisibles in the mechanical arguments. Archimedes himself says only that the *tropos* is without proof (*χωρὶς ἀποδείξεως*).[117] Archimedes had clearly distinguished between Democritus' and Eudoxus' contributions to the volume of cones and pyramids. His admiration for Democritus' contribution (*οὐ μικρὰν μερίδα*) contrasts with other statements on this problem, in which he mentions only Eudoxus. Thus, although both Democritus and Eudoxus have contributed to the solution of the problem of the volume of the cone and pyramid, only Eudoxus has finished the argument by providing proof. And so the moment of discovery or the process of discovery is not what Greek mathematicians are searching for; rather, the final formal proof has priority in the hierarchy of mathematical achievement. Thus despite his claim of heuristic usefulness, Archimedes presents Eratosthenes and us with a logic not of discovery – which we would associate with heuristics – but of formalization.

Archimedes rejects the novelty of the *tropos*' approach because of the standards of proof of the mathematical community. Archimedes' *tropos* is an innovative integration of mechanical aspects into mathematical argument but the resulting conclusion offers only starting points for a proof in formal mathematics. The paradigmatic section of the *Ephodos* text, *Ephodos* 426-438, thus demonstrates a formalization of traditional methodological criteria over innovative ones.

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[116] *Ephodos* 276-77.
[117] *Ephodos* 103-04.

TRADITION

Chapter 4: The Empiricists

In this chapter I suggest that Empiricism can be seen as a re-assertion of the doctor's role of caregiver, rather than as a formal researcher into nature. I offer a re-reading of the debate between select Empiricists and Rationalists of the third and second centuries BCE with examples drawn from pharmacology, surgery, and Hippocratic exegesis.

4.1 EMPIRICIST HISTORIOGRAPHY

The Empiricists were a Greek medical sect (αἵρεσις) of the Hellenistic and Imperial period. The word 'sect' refers to a group of individuals with common beliefs and practices, not necessarily an institution or a school building. The Empiricists doctors came from Alexandria, Antioch, Cyrene, Tarentum, and other cities, and practiced medicine all over the Greek eastern Mediterranean. As their name suggests, they valued experience (ἐμπειρία) above all else in medical practice. The sect seems to have had wide success and been as long lived as other Hellenistic medical schools; Appendix C presents a chronological prosopography of the three main Hellenistic medical sects: Empiricists, Herophileans, and Erasistrateans.[1]

So the Empiricist sect began in the Hellenistic period, founded by Philinus of Cos, a student of Herophilus.[2] But we at once face textual problems: no fragments from

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[1]The ancient evidence assembled by Deichgräber (1965) knows twenty Empiricists, comparable in number to the number of physicians from other major Hellenistic medical sects. (Keyser and Irby-Massie (2008: 460) point out that there is an Empiricist physician "Kallikles" mentioned by Galen unknown to Deichgräber's (1965) collection. It seems probable that this Callicles is an Empiricist near Galen's time, rather than a Hellenistic doctor.) Von Staden's (1989: 445-578) collection of fragments of the Herophileans lists nineteen Herophileans. The medical index of names of physicians in Keyser and Irby-Massie (2008: 1006-1011) lists eighteen Erasistrateans but only fourteen are known for certain as Erasistrateans; see Appendix C footnote 60.

[2] Deichgräber (1965: 333): "Die Zeit des Philinos von Kos ist auf etwa 250 v. Chr. bestimmt durch die the Nachricht der Εἰσαγωγή [sc. ἢ ἰατρός 14.683K = Empiricist fr. 6 D], daß er persönlicher Schüler des Herophilos gewesen ist." Von Staden's (1989: 35-50) dates for Herophilus' life extend to 260/250 BCE. If Deichgräber's date for Philinus is correct, he will have been among Herophilus' last students. There is an

Philinus survive, only testimonia. This is typical of the primary sources of Empiricism. In fact, only one Empiricist text of the Hellenistic period, Apollonius of Citium's *Treatise on Hippocrates' On Joints*, is wholly extant. We do have numerous testimonia and verbatim quotations of the Empiricists, collected in Deichgräber (1965), as well as testimonia for Empiricist doctrines without ascription to any individual Empiricist author in Celsus and Galen who, although somewhat critical of all sects, are more sympathetic to the Rationalists than the Empiricists. Their most important treatises presenting Empiricist doctrines are Celsus' *Praefatio* to *De Medicina* and three treatises of Galen, *On Sects for Beginners, Outline of Empiricism,* and *On Medical Experience*. *On Sects for Beginners* survives in Greek, *Outline of Empiricism* in a medieval Latin translation by Niccolo of Rheggium, and *On Medical Empiricism* in a medieval Arabic translation by Hunain and Hubaish.[3] A reading of the source material must therefore be conscious of authorial bias and the textual problems attendent on multiple language translations.

In spite of the historiographical problems involved in working with Empiricist material, Deichgräber (1965) emphasizes the state of preservation of the Empiricist methodological fragments: "Aus allem sieht man, wie stark sein Interesse an den Lehren dieser Schule ist. Es ist der wichtigste Faktor in der Überlieferung der empirischen Fragmente geworden."[4] Deichgräber had maintained that Empiricist methodology did not change from its founding but subsequent scholars have corrected Deichgräber's analysis.[5] For example, in *On Medical Experience* Galen is arguing against the soritic

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additional testimonium, Erotian 4 = Empiricist fr. 311 D, that Philinus and the Herophilean Bacchius of Tanagra (for whom see von Staden (1989: 484-500)) were contemporaries, but this piece of evidence is used to date Bacchius rather than Philinus. In general the earliest history of the Empiricist school is very lacunose and Deichgräber's (1965: 163-68) datings for the earliest Empiricists – Philinus of Cos, Serapion of Alexandria, and Glaucias of Tarentum – seem to be based on a rough span of 25 years (i.e. a generation) between individuals, with only the dating of Philinus somewhat secure. Serapion of Alexandria does cite Andreas of Carystus, a Herophilean murdered in 217 BCE. On the basis of his citation of Andreas (Galen *De compositione medicamentorum secundum locos* 13.343-4K = Andreas fr. 29 vS = Empiricist fr. 151 D) von Staden (1989: 474) dated Serapion's *floruit* to 200 but in a later article (1997a: 941) returned to Deichgräber's dating. Evidence of citation does not necessarily imply that Serapion is a generation later than Andreas: Deichgräber's dating of Serapion is likely correct. Yet Deichgräber's schema of the dates of the early Empiricists is of course without evidence (apart from Philinus). Unfortunately we are not likely to do better with the evidence currently at our disposal.

[3] Translations of all three texts are in Frede (1985).

[4] Deichgräber (1965: 5).

[5] See Deichgräber (1965: 253) and Frede's correction (1987: 93).

argument which Asclepiades of Bithynia, a Pneumatist, had leveled against the Empiricists.[6] The claims Galen makes for the Empiricists in *On Medical Experience* make it clear that the sect of Galen's time had become considerably less dogmatic about denying the role of reason in medicine than at its founding. Thus any attempt to represent the doctrines of the Empiricist school is constrained by our extant sources and the fact that the doctrines of the school seem to have changed over time. If a diachronic presentation of the doctrines of the Empiricists to 200 BCE eludes us, we can still recover a synchronic presentation of the doctrines of the sect by the time of our first extant text, Celsus' *Praefatio*. At the minimum I will therefore aim to present a picture of Empiricist doctrine informed by Celsus and the fragments of pre-Celsian Empiricists collected by Deichgräber.

4.1.1 Doctrinal Changes in Empiricism

But the evidence allows us to go even further than this. Michael Frede (1987) has convincingly argued that changes in the doctrine of the Empiricists ought to attributed to Heraclides of Tarentum, *fl.* 75 BCE.[7] In a well-known passage on the resetting of the hip

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[6] Although I have not seen Walzer's (1944) edition of *On Medical Experience* and have used only Frede (1985), chapter 19 of *On Medical Experience* = Frede (1985: 80-1) seems to be an insertion of later tradition (perhaps Arabic?) because chapter 18 would flow better into chapter 20 without 19. I have been unable to ascertain whether Walzer remarks on this possibility.

[7] Frede (1987: 89-96). Approved also by Guardasole (1997: 25): "È stato affermato, da parte di studiosi moderni che Eraclide introdusse elementi razionalistici nella tradizione empirica; in particolar modo Frede ha posto l'accento su un passo di Galeno, nel quale – pur non citando Eraclide la sua fonte – è chiaro egli accoglie par la causa dell'affezione la spiegazione fornita da Egetore erofileo nel suo commento al tratto ippocratico *de articulis*. Avrebbe, quindi, tentato una sorta di mediazione tra le due scuola. Questa conclusione risponde a verità ma sono necessarie ulteriori precisazioni: la convergenze, peraltro numerose, riscontrabili nell'opera di Eraclide con le posizioni di appartenenti alla scuola dommatica sono da spiegare altrimenti che con il suo tentativo di far semplicemente da mediatore fra le due tendenze, ma piuttosto con il fatto che egli assegnava al ratio una parte precisa nei principî di conoscenza, permettendo cosí un certo moderato 'ampliamento dommatico' della dottrina empirica, purché ciò fosse utile per l'arrichimento delle possibilità terapeutiche. Inoltre non si deve prescindere mai dalla considerazione che, pur con moderate concessioni alla dottrina razionale, per il Tarantino il centro dell'attività medica fu sempre e solo l'esperienza. possiamo affermare che alla base dell'intiera sua attività di ricerca ci fu unicamente il progresso della scienza medica e, di conseguenza, il bene dell'uomo." I am not sure how Guardosole intends to disagree with Frede's position, since Frede meets her reservations that Heraclides remains ultimately an Empiricist and thus values experience above all: Frede's view is that Heraclides values reason as a positive force only insofar as it contributes to therapy, Guardosole's "purché ciò fosse utile per l'arrichimento delle possibilità terapeutiche."

bone (a medical possibility not entirely understood until the 19th century) Galen quotes Heraclides, who argues that resetting the hip is possible:

> Ὅσοι δὲ οἴονται μὴ μένειν μηρὸν ἐμβληθέντα διὰ τὸ [μὴ] διεσπᾶσθαι τὸ συνέχον νεῦρον πρὸς τὴν κοτύλην τοῦ ἰσχίου τὸν μηρόν, ἀγνοοῦσιν ἐν τῷ καθόλου τρόπῳ τὴν ἀπόφασιν ποιούμενοι. οὐ γὰρ ἂν Ἱπποκράτης καὶ Διοκλῆς ἀνέγραψαν ἐμβολάς, ἔτι δὲ Φιλότιμος, Εὐήνωρ, Νηλεύς, Μόλπις, Νυμφόδωρος, ἄλλοι δέ τινες. ἡμεῖς δ' ἐπὶ δύο παιδίων ἐκρατήσαμεν τῆς προθέσεως. πολλάκις τοί γε καὶ μᾶλλον ἐπὶ τῶν τελείων ὀλισθαίνει πάλιν τὸ ἄρθρον. οὐκ ἐκ λόγου δὲ δεῖ τὸ πρᾶγμα κρίνειν, ἀλλ' ἐπειδή ποτε καὶ μένει, διαλαμβάνειν μὴ διὰ παντὸς ἀποσπασμὸν γίνεσθαι τοῦ νεύρου, ἀλλὰ καὶ ἀποχαλᾶσθαι καὶ συστρέφεσθαι πάλιν, ἐπειδὴ τοῦτο ζητεῖν ἐστι χρήσιμον, ἀλλ' οὐ παντελῶς κοινόν.
>
> However many think that the femur when set does not stay in place on account of the fact that the tendon holding the femur to the socket of the hip separates, they do not know in a general way when they make their claim. For Hippocrates and Diocles would not have written up their settings, as did Philotimus, Euenor, Neleus, Molpis and Nymphodorus and certain others [if this were not possible]. We established the fixture in the case of two boys. Frequently at least the joint on the end slips again and there is no need to determine this event by reason, but since the bone sometimes stays fast it is necessary to suppose that some separation of the tendon does not always happen but sometimes it relaxes and again tightens – since to investigate this is useful but not entirely necessary.[8]

Heraclides argues against those who claim that the hip cannot be reset; one of these critics we know to be Hegetor the Herophilean, a Rationalist doctor of the mid-second century BCE discussed below in 4.3.4. Hegetor's claims against reduction of the hip concern inferences drawn from anatomy, a claim of deductive reason. Heraclides' response to Hegetor and Rationalist critics shows many features encountered in other Empiricists authors: an appeal to personal experience, arguments to authority, the contrast between reason and experience, and the notion of the useful. Still, Frede (1987) notes that Heraclides also offers a conditional deductive inference: if the femur can sometimes be reset (as Heraclides knows from personal experience and from the report of earlier doctors), perhaps the tendon which holds the femur in the hip socket does not invariably tear but simply slackens so that the bone becomes dislocated, then tightens again allowing the bone to be reset. Heraclides "draws an inference from the observable

[8] Heraclides *apud* Galen *Comm. In Hipp. De Artic.* 18A.735-6K = Empiricist fr. 175 D = Heraclides fr. 43 Gu.

facts to an alternative theoretical account of what happens";[9] Heraclides' theoretical account concerns non-observable phenomena, going beyond the usual Empiricist purview of observable causes. Furthermore, Frede argues that Heraclides does not thereby adopt his theoretical account as a superior theoretical account to that of the Rationalist critic; for Heraclides the account remains an instrumental, provisional account of natural phenomena and not a condemnation of reason (λόγος). Heraclides' addendum "to investigate this is useful but not entirely necessary" importantly captures the nuance in his Empiricist position: "Heraclides means to say that it is positively useful to have theoretical views of some kind, positively useful, but not necessary."[10] Frede therefore distinguishes between seeing a positive value in reason, a position which later Imperial period Empiricists called ἐπιλογιστικὴ πεῖρα "epilogistic experience",[11] and valuing theoretical entities *per se*. He finds that Heraclides sometimes did value theoretical entities in so far as they might be useful to "advance the state of the art."[12] Whether Heraclides did in fact invent the process of *epilogismos*, a productive reasoning about temporarily non-evident things that later Empiricists such as Theodas *fl.* 125 CE and Menodotus *fl.* 125 CE recognize, Frede's reading demonstrates that some Empiricists attributed a positive value to reason earlier than previously supposed.

Although Celsus seems mostly to bypass this doctrine of Heraclides in his account of the Empiricists, his own favored mediation between Empiricists and Rationalists has surprising affinities with Heraclides' position.

> igitur ut ad propositum meum redeam, rationalem quidem puto medicinam esse debere, instrui uero ab evidentibus causis, obscuris omnibus non ab cogitatione artificis, sed ab ipsa arte reiectis. incidere autem uiuorum corpora et crudele et superuacuum est, mortuorum discentibus necessarium, nam positum et ordinem nosse debent, quae cadauer melius quam uiuus et uulneratus homo repraesentat. sed et cetera quae modo in uiuis cognosci possunt, in ipsis curationibus uulneratorum, paulo tardius sed aliquanto mitius, usus ipse monstrabit.

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[9] Frede (1987: 91).
[10] Frede (1987: 92).
[11] Galen *Subfiguratio empirica* 4 = Empiricist fr. 10b p.50.3 D, where the context is the reason or justification used in "transition from the similar". Galen attributes ἐπιλογιστικὴ πεῖρα to Theodas of Laodicea (*fl*. 125 CE), on whom see Deichgräber (1965: 214-15).
[12] Frede (1987: 93).

> Therefore, to return to my subject, I think that medicine ought to be rationalist but constructed from evident causes, with all hidden causes rejected not from the consideration of the practioner but from the art itself. Moreover to cut into bodies of the living is cruel and superfluous, [but] it is necessary for learners [to cut into the bodies] of the dead, for they ought to know the position and arrangement, which a cadaver shows better than a living and wounded man. But as for the rest which can only be known in the living, need itself will show in the very cures of the wounded, a little slower but somewhat more gently.[13]

Celsus constructs a *via media* between the two medical camps of Rationalists and Empiricists.[14] He agrees with the Empiricists that vivisection is cruel and unnecessary and that only evident causes ought to be admitted into medicine. He agrees with the Rationalists that dissection is necessary to understand anatomy, the arrangement and position of interior body parts. Celsus' position on causality is careful to insist on the potential practical value of considering hidden causes, seemingly opposed to evident causes. (The distinction is founded on a Hellenistic philosophical divison between *πρόδηλοι αἰτίαι* and *ἄδηλαι αἰτίαι*, a contrast between visible and invisible causes.) Celsus' claims about causality seem very close to Heraclides' position that "to investigate [invisible causality] is useful but not entirely necessary." Nevertheless, Celsus claims this position as his own.

Frede finds it surprising that Celsus' own position in the *Praefatio* is aligned with Heraclides': "clearly Celsus could not present this as his own view of the matter, as opposed to that of the Empiricists, if something like it already had been the standard Empiricist view."[15] Yet Mudry (1982), the standard commentary on Celsus' *Praefatio*, argues that Heraclides' book *περὶ τῆς ἐμπειρικῆς αἱρέσεως* was Celsus' source for discussion of Empiricist doctrines.[16] If Heraclides did attribute positive value to reason,

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[13] Celsus *Praefatio* 74-5. Latin citations from Celsus *Praefatio* are from the text of Mudry (1982).

[14] For Celsus' self-fashioning in this regard, see von Staden (1994).

[15] Frede (1987: 94).

[16] Mudry (1982: 73, 84, 115-16). In this evaluation Mudry is following a long line of commentators back to the position of Sepp (1893). Sepp's argument concerned Celsus' philosophical inclination in general and includes Celsus' position vis-à-vis Empiricism, Skepticism, and Methodism, among others. Sepp's argument stands for Celsus' interest in skepticism generally but the evidence he brings to bear on his thesis that Heraclides of Tarentum is the *Quelle* of Celsus' *Praefatio* is slim. Sepp (1893: 7) can offer no more evidence than the claim that Heraclides was the first to use the name Empiricist: "Es lässt sich aber auch warhrscheinlich machen, dass Celsus seiner Geschichte der Empirie einen Empiriker zu Grunde gelegt

it would be difficult, as Frede argues, for Celsus to present an account of Empirical knowledge at odds with his source and, further, for Celsus himself to present a view as his own which he took from the reforming Empiricist.[17] While the impasse in *Quellenforschung* of Celsus is still unrecognized,[18] Frede's case against Heraclides of Tarentum being Celsus' source for Empiricist doctrine implies that Celsus' source adopted an Empiricist position different from Heraclides: regardless of whether the source post-dated Heraclides, he will have presented a view of Empiricist doctrine more traditional than the innovative Heraclides. For this reason, Celsus presents a view of Empiricist doctrine whose ideas ante-date Heraclides, that is, largely a collection of second-century BCE views.

4.1.2 Sectarian Self-Fashioning

A Hellenistic medical sect is a group of individuals with a set of common beliefs and practices. Yet as Frede's analysis of Heraclides of Tarentum showed in 4.1.1, the

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habe. Denn es fällt auf, dass er den Empirikern, statt sie, wie die introductio des Ps. Galen, durch Philin an Herophilus anzuknüpfen, neben den andern, als logisch bezeichneten, Sekten eine völlig unabhängige Stellung anweist. Dies war der Standpunkt, welchen Heraklid von Tarent einnahm, dem Celsus auch sonst, trotz gelegentlichen Tadels, viel häufiger folgt, als er angibt. Denn obwohl Heraklid nach Galen anfags selbst, ebenso wie sein Lehrer Mantias, zu den Herophileern gehört hatte, trat er doch nachn seinem Übergange zur Empirie als heftiger Gegner derselben [so des Bachius, Andreas, Zeno] auf und rief durch seins Kampschrift gegen des Herophilus Pulslehre eine langdauernde literarische Fehde hervor. Er ist es auch, der in seiner Schrift über die empirische Lehre, die Galen in 7 Büchern commentiert hat, zum erstenmale den Namen Empiriker gebraucht, um die Schule des Serapion und Glaucias, welche der Empirie den Vorzug gaben, damit zu bezeichnen. Celsus und der gleichlautende Bericht der subfiguratio empirica knüpfen deshalb beide, letztere, ohne weitere Vorgänger zu nennen, den Namen Empiriker an seine Person." Sepp (1893: 8) cites Celsus *Praefatio* 10 for his claims: *aliquanto post Heraclides Tarentinus et aliqui non mediocres viri secuti ex ipsa professione se empiricos appellaverunt.*

Yet Sepp is mistaken that Heraclides was the first to use the term ἐμειρικός to describe himself and his style of medicine. In a Herculaneum papyrus, *P.Herc.* 1012, Demetrius Lacon the Epicurean philosopher *fl.* 100 BCE attacks an Empiricist, Apollonius the Elder, *fl.* 175 BCE and names him ἐμπειρικός (Empiricist fr. 164 D). It seems likely that the name ἐμπειρικός goes back to an early Empiricist, perhaps Serapion of Alexandria, Zeuxis, Glaucias of Tarentum, or Apollonius the Elder. It is unfair to criticize Sepp at length since he did not have source collections for the Hellenistic medical sects (i.e. Deichgräber (1965) on the Empiricists, von Staden (1989) on the Herophileans, Garofolo (1988) on Erasistratus). The source collections of Hellenistic medical sects demand at least that scholars reevaluate the evidence to which we have clung for a century.

[17] Von Staden (1994) on Celsus' own views adds little directly to the problem, although he does point out that Celsus cites very few Empiricists including Heraclides outside of the *Praefatio*. This would complicate, rather than simplify, the theories of Celsian Quellenforschung.

[18] See Stok (1993, 1994), von Staden (1999a, 1999b).

doctrines internal to the medical sects changed over time. What is common to members of a sect or αἵρεσις? Von Staden (1982) attempts to answer the question of what unites the members of a sect; he argues that the Empiricists are united on the main issues whereas the Herophileans are not.[19] He offers, as an example of the Herophilean disagreements, the many definitions and redefinitions of the pulse given by eight different Herophileans.

> [E]ach Herophilean strove for a fresh and more viable definition of the essential nature of the pulse, attempting at the same time to meet objections raised to his precursors' formulations. What might, from a modern perspective, look like sophistic quibbling over minor differences concerning a definition, to most of the participants in this revisionary process was anything but a mere exercise in particidal and fratricidal eristic. Rather, it was a search for a correct understanding of the essential nature of a major diagnostic tool and, simultaneously, a reaffirmation of the value and relevance of theoretical investigations for the clinician. What unites almost all followers of Herophilus is in fact precisely their interest not only in clinical but also in scientific or 'theoretical' medicine, and this is, of course, also what distinguishes them most sharply from their chief rivals in the early period, the Alexandrian Empiricists, who radically reject anatomy and physiology as irrelevant for clinical purposes.[20]

If the Herophileans disagree about what the pulse is, it is not because they find no value in it. Each individual physician reified their sectarian predecessors' definition of the pulse *as an expression of their commitment* to the value of the pulse for theoretical Herophilean medicine. Von Staden can further show that Herophileans engaged in pharmacology and Hippocratic exegesis even as they abandonded Herophilus' procedures and innovations in dissection: pharmacology and Hippocratic exegesis are areas within medicine expressing Herophileans' commitment to their methodological views.

Von Staden's broad sense of what constitutes a sect is correct: the general area of action of physicians manifests a belief in certain kinds of methodological procedures. A Greek medical sect is thus an ideological group: individuals united by common beliefs in the value of particular kinds of scientific methodologies and domains of study. The Herophileans are united in the value of causation and they work in the most common

[19] Von Staden (1982: 82, 85-93).
[20] Von Staden (1982: 87-88).

domains in the Hellenistic period of pharmacology, surgery, and Hippocratic exegesis. The Empiricists too work in these same areas yet they strive to distinguish themselves from the Herophileans, as we will see in 4.3.3-5. Nonetheless, the Empiricists' broad agreement on the values of certain domains and methodologies does not preclude their disagreement about how to pursue those questions of scientific knowledge and healing. There is no unanimous agreement among the Empiricists on particular questions anymore than there is unaminous agreement among the Herophileans.

As an ideological group a Hellenstic medical sect combines the two elements of Kuhn's 'paradigm', discussed in chapter 1.2.3: (1) the example of puzzle-solving that scientists operate with in their daily investigations, and (2) the metaphysical commitment that accompanies the puzzle-solving exemplar. The sect is a social group of scientists ideologically united by their approach. The sect has several paradigmatic puzzle-solving examples. For example, Herophilus' description and use of the pulse in prognosis and therapy as described in chapter 2 is an outstanding exemplar of puzzle-solving for Rationalists. As will be shown in 4.2.2, the Empiricists have many particular examples of problem-solving in two legs of their therapeutic tripod, ἐμπειρία and ἱστορία. Both sects also have beliefs about the ideological consequences of their puzzle-solving exemplars, Kuhn's second sense of 'paradigm': the methodological commitment to a particular areas within the domain of medicine.

There are therefore two types of self-fashioning occurring in the Hellenistic medical sects. First, there is self-fashioning internal to the sect. Herophileans argue against Herophileans; Empiricists argue against Empiricists: the difference between members of the same sect expresses the search for the correct application of their methodological procedures while imitating a puzzle-solving exemplar. Second, there is self-fashioning of sect against sect. Herophileans argue against Empiricists; Empiricists argue against Herophileans: the difference between members of different sects expresses the sect's ideological commitment to their methodological procedures in contradistinction to other scientific approaches.

I will therefore examine the two aspects of Empiricist self-definition separately. Chapter 4.2 considers internal self-definition within Empiricism; chapter 4.3 considers the debate between Empiricism and their rationalist critics.

4.2 POSITIVE EMPIRICISM

4.2.1 Sign-Association

The early Empiricists believed in limited causal chains within the visible realm. The methodological positions that Celsus ascribes to the Empiricists and Heraclides' methodological positions build on a distinction between evident and hidden causes "with all hidden causes rejected not from the consideration of the practioner but from the art itself."[21] The Empiricists limited knowledge of nature to the realm of the visible, the so-called *evidens*.[22] Outside of this visible realm medicine has no sure knowledge of nature and its workings; within the visible realm the Empiricists admited *causae evidentes* into their therapeautic evaluation: the terms *causae obscurae* and *causae evidentes* thus distinguish between causal agents within the sensible and perceptible realm and those not.[23] Therefore the Empiricists are not aetiological nihilists, for they claimed to identify

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[21] Celsus *Praef*. 74.

[22] *evidens* from the roots *ex* and *vid-*.

[23] Previous commentators, debating what causes the Empiricists sanction, have sought to give a particular name associated elsewhere only with Rationalist causal theory to Celsus' *causae evidentes*. Celsus glosses *causae evidentes* in *Praef*. 18 *evidentes uero has* [*sc*. *causas*] *appellant in quibus quaerunt initium morbi calor attulerit an frigus, fames an satietas, et quae similia sunt*. I argue that the visual element is meant by *causae evidentes*.

Mudry (1982: 87-88) claims that the Celsian distinction is equivalent to the causal distintinctions in Galen's treatises on casuality: "Sur le modèle du grec *πρόδηλοι αἰτίαι*, Celse appelle évidentes les causes qui sont de l'ordre du phénomène et peuvent donc être appréhendées par les sens. Les causes que Celse énumère plus bas sous ce nom (*praef.* 18; 52) coïncident avec les causes dites procatarctiques dont Galien donne des exemples dans le traité qu'il leur consacre. La cause procatarctique appartient comme la cause synectique à la tripartition des causes introduite dans la médecine par Athénée d'Attale. Alors qu'il vient de signaler l'identité de la cause obscure et de la cause synectique, Celse ne mentionne pas l'identité de la cause évidente et de la cause procatarctique. Mais il attribue à la cause évidente la meme fonction que Galien à la cause procatarctique, qui est de précéder et de déclencher la maladie." Hankinson (1998b: 24) argues that procatartic causes, at least for Galen, are part of things responsible for bringing the containing cause into focus: "part of what distinguishes an antecedent (*προκαταρκτικόν*) from a preceding (*προηγούμενον*) cause is that the former must be open to inspection, or evident in the sense of the Empiricists, whereas the latter operates inside the body but is not yet the containing (*συνεκτικόν*) cause of the final event." Mudry therefore wishes to construe *causae evidentes* as a synonym for *αἰτία προκαταρκτικά*, causes that are open to inspection and contribute to the contributing cause.

Hankinson (1992: xxviii), moreover, connects Celsus' statement with the Empiricist doctrine of

visible and obvious disease agents and believe in limited causal chains. The early Empiricists held a limited view of the possibility of reason. Heraclides' advance therefore is to extend reason to cover *causae obscurae*, such as the slackening of the hip tendon.

The Empiricists grappled with a notion of medicine confined solely to the visible world. As Celsus says,

> *Differre quoque pro natura locorum genera medicinae et aliud opus esse Romae, aliud in Aegypto, aliud in Gallia. quod si morbos hae causae facerent quae ubique eaedem essent, eadem remedia quoque ubique esse debuisse. saepe etiam causas apparere, ut puta lippitudinis, uulneris, neque ex his patere medicinam. quod si scientiam hanc non subiciat euidens causa, multo minus eam posse subicere quae in dubio est.*
>
> [The Empiricists] also contend that kinds of therapy differ depending on the nature of the places and that there is need for one kind at Rome, a different in Egypt, a different in Gaul. But, <they say,> if these causes which are everywhere the same cause diseases, there ought to be the same remedies everywhere too.

συνδρομή, the collection of information relevant to each case. In a later work Hankinson (1998a: 321) argues that the Empiricists include antecedent causes (Mudry's αἰτία προκαταρκτικά) in the syndrome: "[C]all them causes if you wish … as long as the term is not taken to connotate any commitment to the existence of some arcane causal truth of the matter. Empiricists and Rationalists, then, largely agree (against the Methodists) about the importance of those events classed by the Rationalists as antecedent causes; they disagree about what can be said as to why they are important. The Empiricists allow antecedent causes into his syndrome; but he does not thereby commit himself to believing that they really are *causes*."

Yet the Galenic evidence of the Empiricist causal theory does not hinge on the Rationalist distinctions of causality but only the distinction between visual and non-visual. In *On Sects for Beginners* Galen offers an example of two patients, each bitten by a rabid dog, and how each sect offers to treat him: the Empiricist, unlike the Methodist, distinguishes the dog bite from other bites because it is relevant that a rabid dog (as opposed to a snake) bit him; Galen calls this recognition of the rabid dog's role the συνδρομή which in turn he defines as τὸ γὰρ προειρημένον ἄθροισμα τῶν συμπτωμάτων ἐπὶ τοῦ πυρέττοντος [sc. the circumstances of age, strength, season, place, etc.] ὃ συνδρομὴν καλεῖν εἰσὶν εἰθισμένοι Galen *de sectis ad eos qui introductur* 7.3-5 Helmreich = 1.72 K. Furthermore in *Subfiguratio empirica* chapter 7 Galen discusses the differences between Empirical συνδρομή and Rationalist συνδρομή: *et nimirum nihil prohibebat neque hoc empericam quidem diffinitionem dicere esse propriam rationem rei consistentem <ex> his que evidenter insunt ei, eam vero que dogmaticorum propriam quidem esse non tamen ex his que evidenter apparent.* Empiricist fr. 10b D = Deichgräber (1965: 62-63.26) = Frede (1985: 32-3).

It is difficult to believe that Celsus intends to have the Empiricists distinguish between different causal agents by what they contribute to the causal chain. Furthermore, it would be a reversal of his usual practice for Celsus to intend his Empiricist technical terminology to imply the distinctions of Rationalist terminology. It is more consistent to believe that Celsus' use of *causae evidentes* is meant to follow the Empiricist position. In this usage then, *causae evidentes* covers those examples of αἰτία that begin within the visible realm without intending to distinguish between possible contributions to the containing cause. Insofar as this is causal theory, it is not the causal theory of Galenic antecedent or proceeding causes; it is a causal theory dependent solely upon a visible element.

> Often also the causes are clear, as in inflammation of the eyes, or a wound, but not even from these is a treatment clear. But if the evident cause does not yield this knowledge, so much the less can <a cause> which is in doubt yield knowledge of treatment.[24]

Mudry (1982) points out that the Empiricists here depend on skeptical arguments about causality: "Ils se servent en cela de l'argument sceptique rapporté par Sextus Empiricus (*M.* 9, 246 sqq.) qui réfute la notion de cause en se fondant sur la diversité des effets qu'une seule et même cause serait supposée produire … cet argument vise à nier la notion meme de l'inférence causale."[25] The Dogmatists used ἔνδειξις "indication" to signify an indication of the type of cause that had led to disease and thus the kind of treatment needed. The Empiricists in Celsus' description were aiming at the Rationalists' doctrine of causality: since the same outcome has different treatment in different places, the causal agent cannot be the same; therefore ἔνδειξις is no guarantee of the therapy needed. But the Empiricists were not etiological nihilists. Early Empiricists such as Serapion of Alexandria *fl.* 225 BCE and Glaucias of Tarentum *fl.* 175 wrote books on the so-called tripod of the Empiricists, a methodological program for medicine dependent on particular kinds of sign-association discussed in 4.2.2. The phrase 'etiological nihilists' suggests a disavowl of all types of sign inference; rather, the Rationalist sources only say that the earliest Empiricists disavowed the Rationalist notion of ἐνδείξεις. From its outset Empiricism conducted its positive program entirely within a semiotics of the visible which was not dependent on the Rationlist notion of ἐνδείξεις.

The positive doctrine of the Empiricists was contingent on the logical necessity of the visible; it was equally contingent on a notion of *physis*. Although it may seem to be in the realm of the visible, the Empiricists rejected knowledge gained from the body through dissection. They did not object that knowledge of the internal organs is unnecessary but rather that it is impossible to achieve. To have knowledge of the internal organs in dissection one must cut apart the dead body. But, the Empiricists said, the fact that the body is dead means that there has been a shift in category: if the goal is to gain

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[24] Celsus *Praef*. 30-31.
[25] Mudry (1982: 120-1).

knowledge of the functions of the body, how will we gain knowledge from a functionless body? The dead body cannot be studied as a goal to the *function* of the live body.[26] As Mudry (1982) notes, "la nécessité de l'observation anatomique *in uiuo* est une idée commune à l'ensemble de la médecine hellénistique, sans distinction d'écoles. Elle dérive de Platon et d'Aristote pour qui le cadavre humain n'est plus vraiment l'homme."[27] Furthermore, the Empiricists' rejection of dissection as a category error of the Rationalists explains why the Empiricists did not engage in the comparative anatomy of dissecting animals, as had been done in Aristotlean treatises and Galen too would do: this too was a category error between living function and dead structures.[28]

The Empiricists rejected vivisection too. Celsus claims that Herophilus and Erasistratus practiced vivisection on condemned criminals from the Ptolemaic prisons.[29] Opening the body of the live patient offers access to view natural functions, both interior and exterior. Despite the hermeneutic possibilities of cutting open a live body, the Empiricists rejected vivisection with both an ethical and epistemological argument. First, on moral grounds, they argued that it is cruel to cut into living people.[30] Second, from an epistemological point of view, the Empiricists claimed that the qualities of the interior of the body, when put on open display, are changed out of fear, pain, and many other afflictions.[31] It is unlikely that the Empiricists meant to assert some sympathetic nature of the internal organs, such as softer organs are more susceptible to the interruption of

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[26] Celsus *Praef*. 42-43. The key term is *quale… tale* – a qualitative shift from *vivo homine* to *moriente* and *mortuo*.

[27] Mudry (1982: 106-7).

[28] The pig at least figures in both [Hipp.] *On the Heart* and Gal. *Ana. Am*., the account of the laryngeal nerve. Von Staden (1989: 179) argues that Herophilus may have dissected a cow's brain to see the *rete mirabile*, a feature which does not occur in human anatomy but does in pigs, sheep, goats, and oxen. At any rate, the dissection of animals has a long tradition in the history of Greek medicine.

[29] Celsus *Praef*. 23. Von Staden (1989: 144-153) has convincingly argued that Celsus' report is trustworthy. He emphasizes how the pioneer environment of Greek colonists in Alexandria could have given support to sanctioned breaking of taboos of previous society; and how the later Egyptianization of Alexandrian and Ptolemaic life may have revived fears and taboos of violating the human body, dead or alive. The most persuasive comparative evidence is Galen's testimony that Mithridates VI and Attalus III tried antidotes to known poisons on condemned criminals; cf. von Staden (1989: 147.n18).

[30] Celsus *Praef*. 40 *id uero quod restat etiam crudele, uiuorum hominum aluum atque praecordia incidi*.

[31] Celsus *Praef*. 41 *nam colorem, leuorem, mollitiem, duritiem similiaque omnia non esse talia inciso corpore qualia integro fuerint quia, cum corporibus inuiolatis, haec tamen metu, dolore, inedia, cruditate,*

nature. At the very least the point stands, that interior function *might* be impaired by the unnatural action of vivisection. Whether the Rationalists felt this was a strong argument or merely an *ad hoc* justification, no Rationalist source seems willing to have pursued the matter against the Empiricists.[32]

Therefore the Empiricists limited their practice within a semiotics of the visible and natural. There are many types of signs possible within this epistemological domain: sign as natural bond, sign as association, sign as logical necessity. The major account of ancient sign theory comes from Sextus Empiricus, who distinguishes between the commemorative sign, ὑπομνηστικὸν σημεῖον, and indicative sign, ἐνδεικτικὸν σημεῖον: "They call the commemorative sign that which having been evidently co-observed with the signified, together with its occurrence when the signified matter is non-evident, leads us into a recollection of what was co-observed with it but is now not manifest."[33] The commemorative sign appears as a link between two evident things: itself and the evident signified. The observation of the commemorative sign is therefore not the as-yet-unobserved-mark of the signified but the recollection, ὑπόμνησις, of the signified. The indicative sign, by contrast, is "as they say, that which has not been evidently co-observed with the signified, but from its own nature and constitution signifies that of which it is a sign."[34] The indicative sign is a mark standing in for the signified, whether seen or unseen; there is a natural relation between the indicative sign and its signified.

But the Empiricists rejected out of hand the idea of signs as logically necessary, the notion of the causal chain. For if a sign was logically necessary, it was necessary that something give rise to it. This regress may lead back to a causal agent not within the

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lassitudine, mille aliis mediocribus affectibus saepe mutentur, multo magis uerisimile esse interiora, quibus maior mollities, lux ipsa noua sit, sub grauissimis uulneribus et ipsa trucidatione mutari.

[32] The Rationalists in Celsus' *Praefatio* seem unashamed of the reports of vivisection and even argue for it (23-26). Mudry (1982: 109) argues that the Rationalists refer to vivisection in a historical sense only, the work of Herophilus and Erasistratus. Nonetheless, it is possible to see Celsus' presentation here as part of the Empiricist critique of Rationalists, historical fact embellished for the presentation of the scandalous attitude of the Rationalists toward *dissection*, which is the real target of Empiricist critique. It is possible that Hegetor the Herophilean *fl*. 120 BCE, discussed below in 4.3.4, did try to dissect human bodies in imitation of Herophilus. Still the evidence is very slim that anyone in the Hellenistic period after Herophilus and Erasistratus did try to dissect human bodies.

[33] Translations are by Allen (2001: 109) from Sextus *PH* 2.100-1.

[34] Translations are by Allen (2001: 109) from Sextus *PH* 2.100-1.

realm of the visible and natural; and thus when the Empiricists rejected the process of causality and notion of a logically necessary sign, they rejected the indicative sign, *ἐνδεικτικὸν σημεῖον*.

The Empiricists espoused a positive doctrine of sign-association, which Michael Frede (1990) has called 'memorist'. In Sextus' terms, this is the doctrine of the commemorative sign. The commemorative sign does not stand for its signified but only associates with it in the memory of the observer. The act of observing the commemorative sign and recollecting the signified is not so much knowledge and reasoning *per se* as association. Yet the Empiricist embrace of the commemorative sign seems at odds with *having knowledge*. Could doctors merely associate commerative signs with their signifieds as a reliable basis for knowledge? The Empiricial response will be that there is no secure and reliable sign other than the commerative.

4.2.2 The Empiric Tripod

The methodological means by which Empiricists obtained medical knowledge was called the tripod. In the three legs of the *τρίπους* of Serapion of Alexandria *fl.* 225 BCE, *ἐμπειρία* "experience", *ἱστορία* "research", and *ἡ τοῦ ὁμοίου μετάβασις* "transition of the similar" are the means by which medical knowledge is obtained.[35] Von Staden (1975) has convincingly argued that *ἐμπειρία* in Empiricist doctrine does not mean experiment but refers to the passive observation of nature.[36] This may come in the form of happenstance or a natural event. Von Staden offers the examples of a headache cured, respectively, by an accidently cut forehead or by a nosebleed. In neither case is the cure for the headache a process of trial and error but rather an event with attendent circumstances. The tracing of the connection between the event – the cut forehead or the nosebleed – and the cure – the disappearance of the headache – is the work of sign-association. Note that von Staden's example of *ἐμπειρία* implies *αὐτοψία* "self-

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[35] Von Staden (1975: 188). The Empiricists regarded Serapion of Alexandria as the inventor of the tripod but in fact debated among themselves the extent to which he used *ἡ τοῦ ὁμοίου μετάβασις*; see Deichgräber (1965: 164-5). Serapion's book was called *Διὰ τριῶν*; a later Empiricist, Glaucias of Tarentum *fl.* 175 BCE wrote a book called *Τρίπους*. What relationship Serapion had to Philinus of Cos, the first known Empiricist, is unclear.

[36] Von Staden (1975: 187-192).

inspection": the visual element comes to the fore. Galen, a Rationalist, says that Empiricists equate ἐμπειρία with ἡ γὰρ τῶν πλεστάκις καὶ ὡσαύτως ἑωραμένων τήρησις "for experience is observation of things seen to happen in a similar manner on multiple occasions".[37] That is, it is not enough that the association between the sign – the cut forehead or the nosebleed – and the signified – the cured headache – happen only once, but it must happen multiple times and be observed by the doctor. It was a matter of notorious dispute just how often an event needed to happen for the inference to the signified to count as experience;[38] but, whatever the frequency, the procedure of observation and association between visible sign and signified is clear. From the basic tool of ἐμπειρία, correlation of events, the Empiricist gained most of his understanding of medicine.

The Empiricist attitude toward knowledge of anatomy belongs under ἐμπειρία too. Celsus' presentation of the Empiricists, for instance, rejects dissection and vivisection but admits the possibility of investigating interior anatomy from a patient's chance wound:

> Si quid tamen sit quod adhuc spirante homine conspectui subiciatur, id saepe casum offerre curantibus. Interdum enim gladiatorem in arena, uel militem in acie, uel uiatorem a latronibus exceptum, sic uulenarari ut eius interior aliqua pars aperiatur, et in alio alia. Ita sedem, positum, ordinem, figuram, similaque alia cognoscere prudentem medicum non caedem sed sanitatem molientem, idque per misercordiam discere quod alii dira crudelitate cognorint.
>
> If, however, there is something which can be observed while the patient still breathes, chance offers it to the doctors. For sometimes a gladiator in the arena, or a soldier on the battle-line, or a traveler attacked by robbers is so wounded that some interior part is exposed, and in another man a different part is exposed. In this way the wise doctor learns the location, position, arrangement, shape, and other things likewise while practicing not slaughter but health, and he learns through mercy what others learned by savage cruelty.[39]

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[37] Von Staden (1975: 190).

[38] Galen's *On Medical Experience* sets out the soritic argument of Aesclepiades against the Empiricists on the very matter of just how often an event needed to happen for the inference to count as experience and thus be used as the basis for treatment. Galen for his part rejects Aesclepiades' argument but the point remains that opponents of Empiricism took the notion of *frequency* seriously. The Empiricists of course took frequency seriously but refused to be drawn into the debate about the precise number of times an event must reoccur.

[39] Celsus *Praef.* 43.

Mudry (1982) comments on this passage: "Tout en rejetant catégoriquement la vivisection, les empiriques admettent pourtant que la connaissance de certaines particularités des organs internes, celles qui ne sont pas altérées par l'effet des blessures, peut être utile au médecin (la dissection, qui ne fait connaître que des organs morts, est exclue)."[40] In so far as some knowledge of internal anatomy may be useful for treatment, the Empiricists accept the possibility of such associative-signs. However, Mudry points out that the Empiricists do not suggest another direct route to anatomical knowledge in place of dissection.[41] Just as in Celsus' presentation, the Empiricists adopted a technique of τραυματικὴ θέα "wound observation": the passive observation of the interior of the body when exposed by happenstance or a natural event. Again, this knowledge per se is really the connection of the sign of the interior organ with the wound or impairment in the patient's functioning. The association of exterior wound and interior organ may have been a rarely observed occurance, but if it was visually observed, there was no reason why the assocation between the organ and the effect of the wound should be excluded from the doctor's ἐμπειρία.

Now ἱστορία "research", the second leg in the Empiricist tripod, was the aggregate collected experience of previous physicians – cures and their attendant visible circumstances that have been written down. ἐμπειρία required the observation and inspection of the individual physician but clearly no physician could possibly observe all attendent circumstances for the same disease, much less for all diseases. Thus ἱστορία served as a supplement to the individual Empiricist's own experience, the record of other physician's experiences of the tracing of associated signs and signifieds. These other physicians do not necessarily need to be Empiricists, although Galen records that Empiricists debated about this point.[42] Naturally not all ἱστορία was reliable but the Empiricists are not without recourse to judge the truth or falsity of previous doctors'

[40] Mudry (1982: 137).
[41] Mudry (1982: 107): "Il est révélateur à ce propos que les empiriques, qui refusent la dissection, n'envisagent pourtant pas d'autre méthode d'investigation anatomique que la connaissance directe."
[42] Empiricist fr. 10b D = Deichgräber (1965: 66).

ἱστορία: the primary criterion was always be one's own ἐμπειρία.[43] We should take seriously the notion of a research program in ἱστορία; yet it is not so much the Empirical sect but the individual physician who aimed to expand his knowledge. The greater the individual doctor's accumulated associations between signs and signifieds the better understanding the individual physician had of the case at hand. Empiricist ἱστορία was always at the employ of the individual doctor.

The third leg of the tripod is, in its full form, ἡ ἀπὸ τοῦ ὁμοίου μετάβασις τῷ ὁμοίῳ, "transition from the similar to the similar". This is the most disputed element of Empirical doctrine; the Empiricists themselves debated whether it was rightly attributable to Serapion and whether it might be rightly used by a strict Empiricist. Hankinson (1998a) has pointed out that the effectiveness of this notion of transition depends on the extent to which a doctor might construe this notion – whether it might embrace causality, reason, or the non-visible.[44] Hankinson shows that the Empiricists used transition in a heuristic manner, part of the element of discovery rather than justification.[45] Galen's *Outline of Empiricism* shows Empiricists using transition from the similar on elements that are visually similar – a hand and a foot – or similar in location – in the belly – or similar in their effects – such as quince and medlar on diarrhea.[46] All these elements can be understood to be similar in either a visual or natural way. However, Galen's Empiricist in *Outline of Empiricism* warns against transitioning from elements based on a shared common property. For example, in the case of drugs it is not simply enough that aloe and copper flakes are astringent in taste for the Empiricist to mark them as similar. The doctor had to consider what is called *toti proprietati que est in ipsa*, the entire individuality of an item.[47] There are cases we know from associative experience where astringency is the property we are looking for, as in the case of a scarred wound, and

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[43] Empiricist fr. 10b D = Deichgräber (1965: 65.28-69.28) = Frede (1985: 36-39).
[44] Hankinson (1998a: 312-13).
[45] Hankinson (1998a: 311).
[46] Empiricist fr. 10b D = Deichgräber (1965: 70.20-31) = Frede (1985: 37).
[47] Empiricist fr. 10b D = Deichgräber (1965: 72.15-7), which he backtranslates as ἀλλὰ προσέχειν ἀκριβῶς τὸν νοῦν ὅλῃ τῇ ἐν αὐταῖς ἰδιότητι. Frede (1985: 38) offers "put one's mind to the peculiar character of the taste as a whole."

transition from aloe to copper is not a problem; but there are other cases where the astringency of aloe and copper flakes are not the same as the astringency of an apple, as in cases of dysentery. We may attempt to transition from treating the dysenteric patient with an apple to a compound of copper flakes, but both ἐμπειρία and ἱστορία show that the astringency of the copper flakes will not cure the dysentery. The Empiricist's hesitation to consider some feature as designating a class – all astringent drugs – is a mark of how attuned to individual detail Empiricists could be by refusing the logical inferences that come with classes of objects. Furthermore, the appropriateness of transitioning from one element to another is itself justified only by its effectiveness, the αὐτοψία of ἐμπειρία "the self-inspection of one's experience".

It is then clear how an Empiricist could decide how to treat a disease by the three elements of the Empiric tripod. So much then for knowledge of the past. But how could an experientially reasoning person have future knowledge? More to the point, how could an Emipiricist doctor predict the course of disease?

> Empiricists prefer to talk about this [knowledge of prediction] in subjective terms, in terms of expectation (*elpis*) and confidence (*pistis*). Memory produces a certain expectation in us: we may be more or less confident that the person is going to develop cramps. Depending on whether our expectation is fulfilled or not, its degree will be higher or lower in future similar cases. If we have a certain kind of experience, we will have strong enough an expectation to be fully confident in the belief that this person is going to have cramps. But this belief is not a matter of inference, or a matter of some rational insight into the connection between having a certain complexion and going to develop cramps; we may have no idea what the connection is, or whether in fact there is any connection.[48]

The subjective experience of a physician is therefore of critical importance in Empirical medicine. An individual doctor's personal experience is composed of the many associative signs he has observed and the amount of research he has read and considered. It is between these two legs of the tripod that the Empiricist must create his own expectation of the future and test them by the third leg of the tripod.

[48] Frede (1990: 246).

4.2.3 The Doctor's Independent Authority

The Empiricist doctor was constantly at work. There were commerative signs to be noticed, there were *historiai* to be read. Now the Empiricist could not just passively absorb this information. He had to associate the commerative signs and the *historiai* to transition from similar to similar if his therapy was to be effacious. Galen's picture of the Empiricists is of an *active* physician:

> οὐ γὰρ δὶς μόνον ἢ τρὶς ἀλλὰ καὶ πλειστάκις μιμησάμενοι τὸ πρόσθεν ὠφελῆσαν, εἶτ' ἐπὶ τῶν αὐτῶν παθῶν τὸ αὐτὸ ποιοῦν εὑρίσκοντες ὡς ἐπὶ τὸ πολὺ τὴν τοιαύτην μνήμην θεώρημα καλέσαντες ἤδη πιστὸν ἡγοῦνται καὶ μέρος τῆς τέχνης. ὡς δὲ πολλὰ θεωρήματα τοιαῦτ' ἠθροίζετ' αὐτοῖς, ἰατρικὴ μὲν ἦν τὸ σύμπαν ἄθροισμα καὶ ὁ ἀθροίσας ἰατρός.
>
> For having imitated the previous help not only twice or three times but often, then discovering the same effect for the most part in the same diseases they call such a memory a datum and think that it is already trustworthy and part of the *techne*. After many such data have been gathered by them, medicine is the entire collection and the doctor is the one collecting them.[49]

The Empiricist doctor was very far from an inactive and passive physician; rather, the Empiricist constantly tried to associate and improve his ability to diagnose the illness and predict disease from his own experience. The Empiricist doctor was only as good as his ability in his constant tracing of associations.

It has long been recognized that Empiricist critiques of Rationalism draw extensively on the contemporary skepticism of the New Academy.[50] From a certain point of view, skepticism challenges most sources of authority and instead re-authorizes the subject as the judge of truth and falsehood. The reauthorization of the subject's cognitive ability is an epistemological move that places the primary onus and responsibility on the individual skeptic. The epistemological responsibility the skeptic adopts for himself complements the demands the commerative-sign theorist places on himself to associate new and old signs. For doctors who demand of themselves the ability to associate ever more signs, the reauthorization of the individual subject's epistemological judgement that

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[49] Galen *de sectis ad eos qui introdunctur* 2, 1.67K = 3.9-15 Helmreich = Empiricist fr. 15 D. Frede's (1985: 4) translation of *θεώρημα* as *theorem* is an over-translation in my opinion.

[50] See von Staden (1975), Frede (1985: xx-xxxiv), Stok (1993), Hankinson (1998b: 36-43).

skepticism offers is attractive. We should therefore see in Empiricist doctrines a reaffirmation of the independent role of the individual doctor.

The positive doctrine of sign-association that Empiricism offers set the individual person of the physician in the central role. The goal of these tracing of associations was not to build a systematic understanding of nature but rather to provide the doctor a route to successful therapeutics. In short, then, Empiricism aimed to provide the healing physician with tools for his healing practice. From the Empiricist point of view, the quarrel between schools was about the type of role that the doctor plays: the Empiricists emphasize the doctor as clinician and healing practioner in contrast to the Rationalist emphasis on the doctor as researcher and scientist.

There is strong evidence that the Empiricists were concerned with the therapy of the individual patient and his circumstances. The Empiricists were distinguished particularly in the clinical branches of medicine, namely therapeutics and pharmacology. Deichgräber's (1965) collection of fragments for the earliest Empiricists finds books on therapeutics ascribed to numerous individual Empiricists: Serapion of Alexandria *fl.* 225 BCE wrote θεραπευτικά in 3 books,[51] Apollonius of Citium *fl.* 90-70 BCE wrote θεραπευτικά in 2 books,[52] Heraclides of Tarentum *fl.* 75 BCE wrote τῶν ἐκτὸς θεραπευτικά in at least 4 books and τῶν ἐντὸς θεραπευτικά in at least 4 books.[53] Deichgräber (1965) collects material on pharmacology from numerous early Empiricists, some of which may belong in unattested books titled θεραπευτικά. Philinus of Cos *fl.* 250 BCE wrote drug recipes for headaches, asthma, and productive pus.[54] Serapion of Alexandria *fl.* 225 BCE wrote drug recipes for lesions, tumors, patients with pus and stomach disorders.[55] Glaucias of Tarentum *fl.* 175 BCE wrote on complex bandages types[56] and drug recipes for stomach ills, lung problems, and skin pustules.[57] Ptolemaeus

[51] Empiricist frr. 145-148 D.
[52] Empiricist frr. 278-80 D.
[53] For Heraclides' *External Therapeutics* see Empiricist frr. 174-75 D = Heraclides fr. 42 Gu; for Heraclides' *Internal Therapeutics* see Empiricist frr. 179-187 D = Heraclides fr. 48-56 Gu.
[54] Empiricist frr. 135-37 D.
[55] Empiricist frr. 150-52 D.
[56] Empiricist frr. 155-56 D.
[57] Empiricist frr. 157-160 D.

of Cyrene *fl.* 100 BCE wrote drug recipes for headaches;[58] Zophyrus of Alexandria *fl.* 100 BCE wrote antidotes for poisons;[59] Diodorus *fl.* 60 BCE wrote pharmacological recipes for joint pain, skin diseases, and spleen trouble;[60] Lycus of Naples *fl.* 60 BCE wrote drug recipes for snake bites.[61] Heraclides of Tarentum *fl.* 75 BCE was particulary famous for his pharmacological books and wrote at least four different works on the subject.[62] Clearly therapeutic interests are well attested for the pre-Celsian Empiricists.

Galen preserves a general account of Empiricist therapeutics in his *magnum opus* on therapeutics.

> *καίτοι καὶ παρ' αὐτοῖς τοῖς ἐμπειρικοῖς ἡ χωρὶς διορισμοῦ πεῖρα κατέγνωσται· γράφουσι γὰρ ἐν τοῖς περὶ φαρμάκων ὑπομνήμασιν· ἔμπλαστρος πρὸς ἀπαλόχρωτας καὶ παῖδας καὶ γυναῖκας· ἴασί τε τὸν λιβανωτὸν ἐπὶ τῶν τοιούτων φύσεων ἕλκη κοῖλα μηδὲν ἔχοντα σύμπτωμ' ἕτερον ἀνατρέφοντα καὶ πληροῦντα. πότερον δ' ὑγρὰ τὰ τοιαῦτα σώματ' ἐστὶ καὶ διὰ τοῦτο δεῖται μετρίως ξηραινόντων φαρμάκων, ἢ ἄλλη τις αἰτία τοῦ συμβαίνοντός ἐστιν, οὐκ ἐπίστανται. καὶ γὰρ αὖ καὶ πρὸς τὰ γεροντικὰ σώματα γεγραμμένον εὑρήσεις ἕτερον φάρμακον, ἄλλο δέ τι πρὸς τὰ δυσεπούλωτα καὶ ὀχθώδη τῶν ἑλκῶν, καὶ πολλοὺς ἄλλους διορισμοὺς ἐν ἅπασι τοῖς θεραπευτικοῖς ὑπομνήμασι γράφουσιν, ἐξ ὧν ὡς οἷόν τε πρὸς τὴν ἰδιότητα τῆς θεραπευομένης φύσεως ἐξευρίσκουσι τὸ συνοῖσον φάρμακον. ἅπαντες γὰρ οἱ διορισμοὶ κατὰ τὰς τέχνας ἀπὸ τοῦ κοινοῦ πειρῶνται τὸ ἴδιον χωρίζειν· καὶ ὅσῳπερ ἄν τις πλείω διορίσηται, πλησιαίστερον ἀφικνεῖται τοῦ ἰδίου, τοῦτο δ' αὐτὸ τὸ ἀκριβῶς ἴδιον, οὔτε γραφῆναι δυνατόν ἐστιν οὔτε λεχθῆναι· διὸ καὶ τῶν ἐμπειρικῶν τοῖς μάλιστα τῶν ἔργων τῆς τέχνης φροντίσασι καὶ σχεδὸν ἅπασι τοῖς δογματικοῖς ὡμολόγηται τὸ μηδεμίαν οἷόν τ' εἶναι γραφῆναι θεραπείαν ἀκριβῶς, ἀλλὰ τὸ λεῖπον εἰς τὸν στοχασμὸν τῆς τοῦ κάμνοντος φύσεως οἱ μὲν ἐκ τῆς ἑκάστου τῶν θεραπευόντων οἰκείας τριβῆς, οἱ δ' ἐκ τοῦ λογικῶς τετεχνâσθαι φασὶ χρῆναι προστιθέναι· οὐδεὶς δ' αὐτῶν οὕτως ἦν εὐχερὴς, ὡς ἅπαντος ἕλκους κοίλου φάρμακον ἓν ἔχειν ἐπαγγέλλεσθαι σαρκωτικόν.*
>
> Although even among the Empiricists themselves trial and error without qualification is recognized, for they write in their works on drugs 'a salve for the soft-skinned and children and women', and they know that frankincense has no different outcome for hollow ulcers of such natures than nourishing and filling <drugs>. Whether such bodies are wet and therefore need drying drugs moderately or there is some other cause for its happening, they do not know. For, once again, you will find a different drug written for aged bodies, and they write

[58] Empiricist fr 167 D.

[59] Empiricist fr. 267 D.

[60] Empiricist frr. 252-55 D.

[61] Empiricist fr. 259 D.

[62] The titles of Heraclides' pharmacological books were *πρὸς Ἀντιοχίδα* (at least 2 books), *πρὸς Ἀστυδάμαντα* (1 book), *περὶ θηρίων* (1 book), *Συμπόσιον* (1 book). Deichgräber (1965) collects these fragments as Empiricist frr. 203-46 D = Heraclides fr. 1-38, 61-70 Gu.

> another for bodies hard to cicatrize and tuberous with ulcers and many other qualifications in all their therapeutic works, from which they discover the appropriate drug as far as possible for the individuality of the nature being treated. For all the qualifications in all parts of the *techne* attempt to separate the individual from what is common: by whatever degree one defines it further, one reaches more closely to the individual, and the individual itself cannot precisely be written nor said. Therefore it is agreed by particularly those of the Empiricists wise in the practice of the *techne* and nearly all the Rationalists that no therapy can be written precisely but – as regards the remainder for the educated guess [στοχασμὸν] of the nature of the patient – some say that there is need to add from the proper practice of each of the physicians but others that treatment must be crafted from reason. No one of them is so suitable that in every hollow ulcer one can promise one flesh-producing[63] drug.[64]

Galen highlights here the individuality of patients in Empiricist therapeutics. Since each patient was unique and his circumstances different (Galen expresses the patient's circumstances in typically Rationalist terms, in terms of individual φύσεις), drugs as a class did not have their appropriate effect unless matched to the appropriate circumstances of the patient. The Empiricist books on therapy stressed the individual circumstances of the patient. This was part of the Empiricist program to reauthorize the individual physician's experience in his tracing of associations: what works for one patient may not work for another. The Empiricist physician had to place the individuality of the patient always at the center of his practice. This is done through the procedure of ἡ χωρὶς διορισμοῦ πεῖρα "trial and error without qualification". The knowledge that Empiricists have of the therapy of their patient does not come from *a priori* knowledge of *physis*, but rather from the repeated application of the experience of treatment: it is a procedure which aims to hit upon the appropriate result.

Since as a general matter Empiricists valued the individuality of the patient and wrote widely on therapeutics and pharmacology, it seems likely that the healing ability of

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[63] See Majno (1975: 176) for more on the concept of 'ulcers' – in our medical language, a flesh wound grown so inflamed and pus-filled that the skin structure and often the muscular tissue underneath has been eaten away and made hollow – and how Greek physicians tried to cure them: "They [greasy ointments] were supposed to make the flesh grow, and so strong was the belief that it required a special verb, *sacrophyésai* or 'making-the-flesh-grow.' Nature was doing it, of course, in those days as well as today; but some still think *they* are doing it."

[64] Galen *de Methodo Medendi* 10.181-82K = Empiricist fr. 112 D. I print Deichgräber's (1965: 151-52) improvements to Kühn's text.

the physician was a primary Empiricist concern. This is not an accident; it is in direct opposition to contemporary developments in early Hellenistic medicine. Herophilus and Erasistratus, the founders of the major Hellenistic Rationalist sects, secured wide anatomical knowledge through dissection and likely vivisection. Further, as the treatment of Herophilus' pulse theory in chapter 2.4.3 argued, their subsequent physiology was bound up with a new vision for medicine regarding the exploration of the interior of the body. The Rationalist emphasis on knowledge about *physis* over healing offered the impetus for Empiricist critiques of Rationalism.

The traditional view of the origin of medical Empiricism emphasizes the factor of knowledge. Frede (1990) summarizes the traditional viewpoint offered primarily by the Galenic treatises on Empiricism for the genesis of the Empirical school.

> This vision of a medical practice, firmly grounded in theoretical insight into the nature of the reality underlying the phenomena of disease, had lost a great deal of its original appeal by the time we come to the third century B.C. By that time there was an abundance of theories, unfortunately all in conflict with one another … Unfortunately these disputes did not lead to a resolution of the points of contention, but only to more sophisticated reformulations of the old positions … It could also easily seem that all these disputes did little or nothing to advance the ability of the doctor to cure patients, to increase the knowledge he could rely on in actual practice. Empiricism arose as a reaction to this situation. The empiricists decided that the quest for a medical theory which supposedly one day would supply medical practice with a firm basis had, at least so far, proved futile and perhaps was fundamentally mistaken, because reason does not have the power to provide us with such theoretical knowledge.[65]

For Frede the genesis of the Empirical school is the skeptical epistemological arguments that the Empiricist advances against the Rationalist. Perhaps this is in fact true; it is certainly the Rationalist point of view. But when "these disputes did little or nothing to advance the ability of the doctor to cure patients," the doctor's role as a care-giver has disappeared in the Rationalist investigation of *physis*. Where, after all, is the role of the doctor's interaction with the patient in Herophilean anatomical dissection or Erasistratean physiological experiments? This is the polemic that the Empiricists directed against the

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[65] Frede (1990: 229).

Rationalists. *We* esteem the Rationalist practices of third century BCE because they resemble what *we* expect from our medical science – experiment, investigation. The Rationalist investigation of *physis* may have been intended to secure "a medical practice, firmly grounded in theoretical insight into the nature of the reality," but in the investigation of *physis* the Herophilean or Erasistratean has become a research scientist, not a caregiver. Yes, the Empiricists disagreed with the Rationalist program of medical knowledge, but this dispute between Empiricists and Rationalists went beyond their symmetrical dispute about how the doctor achieves knowledge: the cultural role of the physician is also at stake.

Galen records a revealing anecdote about the increasing distance of the doctor from the patient in the beginning of the third century BCE in a passage discussing the behavior and professional etiquette of the physican.

> ἔνιοι μὲν γὰρ αὐτῶν ἐσχάτως εἰσὶν ἀβέλτεροι τοιοῦτοί τινες ὄντες, οἷον ὁ Ζεύξις φησιν ὑπὸ Βακχείου γεγράφθαι Καλλιάνακτα γεγονέναι τὸν Ἡροφίλειον ἐν τοῖς Ἀπομνημονεύμασιν Ἡροφίλου τε καὶ τῶν ἀπὸ τῆς οἰκίας αὐτοῦ· νοσοῦντος γάρ τινος, [εἶτ'][66] εἰπόντος τῷ Καλλιάνακτι· "τεθνήξομαι", φασὶν αὐτὸν ἐπιφωνῆσαι τόδε τὸ ἔπος· "εἰ μὴ σε Λητὼ καλλίπαις ἐγείνατο." ἑτέρῳ δέ ταὐτὸ τοῦτ' εἰπόντι φάναι· "κάθανε καὶ Πάτροκλος, ὅπερ σέο πολλὸν ἀμείνων."
>
> For some of them are exceedingly stupid – some people being of this sort, as Zeuxis says that Callianax the Herophilean was portrayed to have been by Bacchius in *Memoirs of Herophilus and Those from His House*: for when some sick person said to Callianax "I'm going to die", they said that he replied with the following verse: "Unless Leto of beautiful children bore you." And they say that he said to another person saying the same thing: "Patrocles too died, who was much better than you."[67]

Bacchius and Callianax were Herophileans, likely direct students of Herophilus, the exemplar of the research-scientist physician, and both likely lived and worked in Alexandria in the first half of the third century BCE.[68] Callianax showed careless insensitivity toward his patients, each of whom fears that he is dying. Callianax cited

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[66] del. von Staden (2006: 31.n72). Perhaps εἶτ' might be part of the direct quotation of the story or sequence in Zeuxis' or Bacchius' book. Certainly von Staden is right to point out that the particle does not make sense within the context of Galen's passage.

[67] Gal. *In Hipp. Lib. VI Epid. Comm.* 17B.145K = 203.18-26 Wenkebach = Empiricist fr. 357 D = Callianax fr. 1 vS = Bacchius fr. 78 vS.

[68] For Bacchius see von Staden (1989: 484-500); for Callianax see von Staden (1989: 478-9).

lines from an unknown tragedian and the *Iliad* in a misguided attempt to reassure his patients of his intellectual knowledge.[69] While the demonstration of wide knowledge in science and literature is typical of the Alexandrian intelligenstia,[70] this particular event was too much even for Callianax's Herophilean colleague Bacchius, who calls Callianax stupid. Bacchius' condemnation of Callianax's behavior implies that not all Herophileans had as inept a bedside manner as Callianax. I suggest that the Empiricist Zeuxis *fl.* 200 BCE, discussed further below in 4.3.5, draws attention to the excesses of Callianax's attitude: demonstration of literary competence does not demonstrate one's caregiving abilities and in this case even harms them. Perhaps Zeuxis argued that if even Bacchius, a Herophilean, agrees that Callianax's behavior was uncouth, Rationalists at large ought to agree with the Empiricists that caregiving and professional decorum are more important in being a doctor than spurious knowledge.[71]

What motivated a Greek to train and practice as an Empiricist? Surely it was these elements of a positive doctrine – a re-authoriziation of the role of caregiver, a re-authorizing of the primacy of vision in knowledge, a reassertion of the uniqueness of the patient and his circumstances – and a complimentary skepticism of the numerously posited natural forces and the taboo practice of dissection. All in all, Empiricism was a reassertion of very traditional cultural elements in the Greek intellectual tradition of the 5th century BCE. From the Empiricist point of view, it is the Rationalists who are the scientific radicals.

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[69] While it is possible that Callianax intended to demonstrate his understanding of the human conditions, i.e. we are mortal unlike the gods, his clumsy choice of allusions does not inspire the patient's confidence that Callianax will sympathetically treat his mortal state.

[70] See Netz (2009a: 174-229).

[71] *Pace* von Staden (2006: 32). Von Staden (1989: 479) ties this anecdote to the increasing literacy of the Herophileans: "It might also be indicative of a growing emphasis on high literacy and philology within the Herophilean school – a trend to which Pliny later attributes the decline of the Herophilean schoool."

4.3 RATIONALISTS AND EMPIRICISTS IN DEBATE

4.3.1 Writing the Sect Debate

In chapter 4.1.2 I argued that Hellenistic medical sects express self-fashioning both in differences within a sect and in differences between sects; in chapter 4.2 I set out positive Empiricism. In 4.3 I will read the debate between select Rationalists and Empiricists of the third and second centuries BCE as the self-fashioning of one sect against another sect in the areas of pharmacology, surgery, and the markings in the case histories of Hippocrates' *Epidemics* III.

Writing a history of the dispute between select Empiricists and Rationalists in the third and second centuries BCE is only one part of the history of medicine from this period. There are good reasons not to read all Hellenistic medicine in terms of sect affiliations:[72] not all doctors working in the Hellenistic period belonged to sects, as Appendix D shows;[73] focusing on the physicians that belonged to sects prioritizes literary evidence over inscriptions, papyri, and other sources and thus paints a picture with only part of the evidence;[74] and it creates an impression of medical orthodoxy instead of doxical heterogeneity.[75] These caveats warn against taking the debate between Empiricists and Rationalists as *the* history of medicine in the Hellenistic period.

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[72] Von Staden (1982, 1989, 1997a, 2006) has consistently resisted this move throughout his career.

[73] Appendix D is a list of all doctors known by name to have lived and worked without being members of any sect in the third century BCE. For further bibliography see Peremans and van't Dack (1950-81), Fraser (1972: 1.369-76), Mastrocinque (1995), Samama (2003), and Keyser and Irby-Massie (2008). The evidence compiled in Appendix D knows seventy-one physicians, the last seventeen of whom come from a single curse-tablet. Arbitrarily excluding the curse-tablet in order to give a lower bound of the ratio between sect and non-sect physicians, twelve physicians of Appendix C in the third century BCE belong to sects compared to the fifty-four of Appendix D who do not; this is roughly a ratio of 1:4. But the actual ratio between sect doctors and non-sect doctors is even higher: first, the evidence from the curse-tablet should be included; and second, evidence of sect doctors is overwhelmingly manuscript evidence, whereas evidence of non-sect doctors comes largely from documentary evidence such as inscriptions and papyri. Further documentary evidence will of course enlarge the numerical divide even further. As an upper bound, the ratio of sect doctors to non-sect doctors in the third century BCE might be as high as 1:7.

[74] Nutton (2004: 128-56) is the best overview of medicine in the Hellenistic period with a balanced picture of evidence from literary and sub-literary sources.

[75] Von Staden (1997a: 958-59): "The agonal heterogeneity charateristic of ancient science and medicine manifests itself both in 'schools' and outside 'schools' or 'sects'. It finds expression, for example, (a) in the doctrinal diversity represented by the existence of rival schools or circles (interschool agon), (b) in the agonal rivalry of viewpoints visible at certain moments within an individual 'school' (synchronic intra-school agon), (c) in the revisionist dynamic characteristic of the history of certain 'schools' over several generations (diachronic or generational intra-school agon), and very significantly, (d) in the existence of

Although these reasons caution against reading all of Hellenistic medicine within the framework of the quarrel between the sects, much of sectarian medicine can and ought to be read precisely within that framework. In 4.1.2 I defined a medical sect as an ideological group: each sect has ideological commitments to the value of a different scientific methodology whereby their external disagreements express their commitment to that domain of medicine or scientific methodology. Not to write the debate between sects as a history of external sect self-fashioning neglects the ideological component of medical sect history.

A further difficulty confronting the writing of this ideological history is the exact nature of the dispute between Empiricists and Rationlists. Frede (1990) has summarized the ancient evidence:

> What is in question in this dispute first of all is: what is it about a case of knowledge that makes it a case of knowledge, rather than mere belief? The rationalists claim that it involves insight and understanding, and – as a rule – some kind of inference or proof, in short some achievement of reason. The empiricists deny this; for them to know something is just to have observed it and to remember it in the appropriate way, to have the kind of experience of it, and with it, which makes us say that we know it. And technical knowledge for them in principle is no different from this; it just involves a rather complex and specialised kind of experience.[76]

According to Frede the debate is an argument about the tools by which doctors advance to knowledge. The protagonists are associated with a certain set of terms: the Rationalists proclaim the necessity of reason; the Empiricists uphold experience at the expense of reason. It is difficult to go far into the debate without using these terms drawn from ancient accounts of the debate – λόγος, ἐμπειρία, τήρησις, ἔνδειξις "reason,

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numerous individuals who had no sectarian affiliation (even if they attracted their own circle or were trained in the circle of a certain physician) … Second, and closely related, such historiographical resistance could be achieved only if the havoc wreaked upon all subsequent medical historiography by the doxographical schematisations of the Hellenistic Empiricists is fully recognised. Brilliant though their theory of scientific method and their epistemology were, in 'doxography' and 'historiography' the Empiricists' thoroughly misleading division of the world into evil ('rationalists', who, as a single, doctrinally identifiable 'school' or 'sect' in fact never existed) and good (Empiricists, who did exist as a doctrinally identifiable, single school) set an enduring historiographic trap, which the Methodists modified somewhat before Celsus, Galen, and others stepped into it, thereby perpetuating the reductive schematisations that obscure the full heterogeneity, ferocious independence, and motley individualism characteristic of Greek and Roman medicine."

[76] Frede (1990: 225-26).

experience, observation, indication" – at which point the redefinition and nuance offered of the key terms by modern scholarship is overwhelmed by the repetition of the simple antithesis *reason* vs. *experience*.

While the antithesis *reason* vs. *experience* describes the epistemological ground of the debate, the internal self-fashioning of the Empiricists adds another tenor to the debate. In the usual cast of the debate between medical sects the Empiricists are cast as reacting against the Rationalists, critics carping philosophical reservations against a scientifically superior program. Yet the usual formulation *the Empiricists criticized the Rationalists* denies to the Empiricist a positive progam of scientific exploration.[77] What motivated doctors to train and practice as Empiricists? The Empiricist movement was reasonably successful and long-lasting over four or five centuries; it cannot have held a negative and antagonistic stance toward its rivals as its sole doctrine. In 4.2 I argued that Empiricism self-fashioning was an ideological program meant to authorize individual physicians to treat and provide therapy for the unique circumstances of their patients.

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[77] My argument is that Empiricist treatises are not purely anti-Rationalist. But Mudry (1982: 113) argues, for example: "nous savons que, dès les débuts de l'empirisme (vers 250 avant J.-C.), ses représentants se sont attachés à fonder leur doctrine et à attaquer le dogmatisme dans des traités au caractère habituellement polémique et agressif." Mudry describes the λόγος ἀντικατηγορητικός, "qui consiste dans la presentation de la doctrine empirique en meme temps que dans la refutation, par le procédé de la contradiction point par point, des positions dogmatiques," known as, "[une] méthode que Galien décrit et dont il reproche aux empiriques l'emploi systématique qu'ils en font dans leur écrits." Mudry suggests that both the πρὸς τὰς αἱρέσεις of Serapion and the περὶ τῆς ἐμπειρικῆς αἱρέσεως of Heraclides of Tarentum were structured in this way; in fact he suggests that the method of point by point contradiction "s'inspire directement de la méthode ordinaire de ces traités empiriques." Mudry is probably right to see Serapion's treatise as an anticategoretic work at least from the title known as *ad sectas* = πρὸς τὰς αἱρέσεις from Caelius Aurelianus and Galen (Deichgräber unhelpfully does not add Galen's testimony about Serapion's title, πρὸς τὰς αἱρέσεις cf. Empiricist fr. 1 D, in his collection of Serapion testimonia frr. 144-153 D); see also von Staden (1982: 78) on Serapion's πρὸς τὰς αἱρέσεις. But I am not persuaded that Heraclides of Tarentum's περὶ τῆς ἐμπειρικῆς αἱρέσεως was an anticategoretic treatise. Deichgräber's (1965) collection of the directly attested fragments of both of these books is very thin: Empiricist fr. 144 D is an off-hand reference in Caelius Aurelianus to Serapion's πρὸς τὰς αἱρέσεις; and there are no directly attested fragments from Heraclides' περὶ τῆς ἐμπειρικῆς αἱρέσεως. Deichgräber (1965) Empiricist fr. 1 is Galen's list of his books written περὶ τῶν τοῖς ἐμπειρικοῖς διαφερόντων, in which Galen states that he has written two books on Serapion's πρὸς τὰς αἱρέσεις and a synopsis in eight books on Heraclides' περὶ τῆς ἐμπειρικῆς αἱρέσεως, itself seven books long. See also Deichgräber's (1965) respective introductions to the individual fragments of Serapion and Heraclides, in which he suggests that these works were *Quellen* for certain Galenic works. I prefer to base our scholarly evaluations first on attested material. In fact, Galen's list of his works in Empiricist fr. 1 D indicates nothing about the contents of these works; and Galen's propensity for longwindedness notwithstanding, eight books would be a long synopsis of a work which was exclusively an anticategoretic treatise. Empiricist doctrine and Empiricist methodological works – if Serapion's and Heraclides' treatises were of this sort – were not solely designed to contradict Rationalist points.

Empiricist theory in the multiple legs of the tripod was a positive program of visible sign-association, as argued in 4.2.1-2. The driving force behind Empiricist research and investigation into nature was the continual tracing of associations that associative-sign theory demands. Furthermore, in 4.2.3 I argued that Empiricism emphasizes the role of the doctor as care-giver against the Rationalist presentation of the doctor as a researcher into *physis*. The criticims of the Rationalists ought to be seen as an integral element of the Empiricist program but not its driving force.

4.3.2 The Asymmetry of the Sect Debate

The debate between sects is asymmetrical. The Empiricists are arguing from a methodological position of sign-association, advocating for the doctor's role as a care-giver for the individual patient. The Rationalists, on the other hand, are arguing for a methodological position in which knowledge of *physis* promises a successful therapy of disease. The Rationalists, Celsus says in his *Praefatio*, agreed that knowledge of the body's interior is necessary.

> *haec necessaria esse proponunt: abditarum et morbos continentium causarum notitiam, deinde euidentium; post haec etiam naturalium actionum; nouissime partium interiorum*.
>
> [The Rationalists] claim that the following things are necessary: knowledge of hidden and containing causes, then evident causes; after these also <knowledge> of natural functions; finally <knowledge> of interior parts.[78]

For the Rationalists in Celsus' presentation, the hidden and containing causes[79] of the body were the most important causal elements in disease aetiology. These are the causes which cannot be understood through observation alone; rather, doctors must have recourse to theoretical speculation to explain the causal origin of disease. The Rationalists also believed that the natural functions of the body are important to

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[78] Celsus *Pref*. 13.

[79] Mudry (1982: 86) suggests that Celsus' *abditae causae* represents the Greek ἄδηλοι αἰτίαι, for the adjective ἄδηλα Cicero *Aca.* 2.54 renders as *incerta* while Caelius Aurelianus translates ἄδηλοι αἰτίαι as *occultae causae*. The Latin translation *occultus* appears to become the standard medieval translation of the term ἄδηλος: Deichgräber's Latineinisch-Grieschisch index (1965: 389-393) lists no occurrences of term *abditus* but glosses *obscurus* with ἄδηλος. Mudry (1982: 86) is right that the term *continentium causarum* "traduit fidèlment" the Greek συνεκτικαὶ αἰτίαι.

understand health and disease: bodily natural functions include not only the action of the visible muscles in the limbs, but also the action of interior organs of the body. Therefore the Rationalist doctor must know the interior parts of the body, in contrast to the Empiricists.[80] The stability of each sect's internal self-definition sect starts from a different understanding of the patient's body; only within each sect is there agreement about whether knowledge of the body's interior is possible and necessary.

The debate between Rationalists and Empiricists is about whether knowledge of the body's interior is necessary for medicine: the problematization of the concept of bodily interiority. Since scientific debate about an issue is ended when a fact becomes set in the blackbox, the blackbox signifies scientific closure according to ANT: yet within the sect debate closure exists only within each individual sect, not between sects.[81] The Rationalist sect attempted to construct a blackboxed fact about the body's interior; the Empiricist sect attempted to deconstruct it. The Empiricists attempted to construct a blackboxed fact that *physis* is unknowable and superfluous for treatment; the Rationalists attempted to deconstruct it. The Rationalists therefore try to place the anatomy and physiology of the body to the center of the debate while the Empiricists operate with a body whose structure and workings are removed from the debate. Since the asymmetry of the sect debate concerns a first-order question of science, the debate crosses the entire domain of ancient medicine: pharmacology, surgery, and Hippocratic exegesis.[82]

4.3.3 Pharmacology

The first text is a treatise *On Venomous Animals* attributed in manuscript tradition to Dioscorides, the herbalist, although scholars since Sprengel in 1830 reject the ascription.[83] The treatise is divided into a long methodological introduction on the nature

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[80] Mudry (1982: 95-96) "Bien qu'elle soit exposée à l'intérieur du développement sur les causes obscures, la doctrine dogmatique commande également l'attitude de ceux qui la professent à propos des fonctions physiologiques dont ils jugent la connaissance nécessaire à l'exercise de la médecine. Aussi, en rejetant la méthode fondée sur la spéculation, les empiriques rejettent-ils explicitement les deux aspects qu'elle revêt dans la médecine dogmatique."

[81] On scientific closure see chapter 5.2.

[82] For ANT see chapter 1.4. The science of each sect can be seen as its own scientific network, with its own chain of associations, hence the asymmetry of the debate between sects.

[83] Von Staden (1975: 197.n53) notes Stoic and Aristotelian vocabularly.

of causes and a listing of herbal cures for various poisonous bites. Touwaide (1992) argues that the two sections ought to be considered separately.[84] He argues that the methodological introduction, our interest here, is best considered not as "un exposé d'auteur, mais une compilation des avis qu'eurent les diverses écoles médicales d'époque romaine."[85] The discussion includes the views of Rationalists, Empiricists, and Methodists. The introduction has certain similarities to the remaining fragments of a doctor Philumenus, *On Venomous Animals,* c. 2nd century CE. Touwaide does not give a definite date for the methodological introduction but suggests that Ps.-Dioscorides and Philumenus share a common Hellenistic source, rather than that Philumenus is the source of Ps.-Dioscorides: Touwaide suggests that the source is the Herophilean Apollonius Mys.[86] Whether the shared source is Apollonius Mys *fl.* 50 BCE it is enough for my argument to suppose that Ps.-Dioscorides reflects the attitude and some of the arguments of the Hellenistic source. I will argue below that the methodological proem of Ps.-Dioscorides dates to the 2nd/3rd centuries CE.

> *τὸ δὲ κυριώτατον ῥητέον ἐστὶ, τὰ μέρη τῆς ἰατρικῆς οὐχὶ ταῖς καταστάσεσι τοῦ σώματος δεῖν διηρῆσθαι, ἀλλὰ φυσιολογεῖν διὰ τὸ σημειωτικὸν ἰδίᾳ ἕκαστον τῶν ἄλλων, ὡς ἐν τοῖς οἰκείοις τόποις ὑποδείκνυμεν. πρὸς τούτους μὲν οὖν οὐ πλείονα ῥητέον. ἐκεῖνο δὲ μᾶλλον παρασημειωτέον, ὅτι καλεῖται μέν ἀναιτιολόγητα τὰ ἀπὸ τῶν ἰοβόλων ζῴων καὶ τὰ ἀπὸ τῶν θανασίμων συμβαίνοντα φαρμάκων. διὰ τοῦτό γε καὶ παρατηρητικῆς τυγχάνει*[87] *ἀναλογητικῆς τε τέχνης προσπεσούσης ἀπόρημα, καθ' ἣν δὴ ὁ λόγος πεπίστευται· οὐδὲ γὰρ ἐν τῷ καθάπαξ τοῦτό ἐστιν ἀληθές· ἀλλ' ἀεὶ τὸ παρέλκον καὶ μηδεμίαν χρείαν ἐπί τινα τῶν ἔργων παρεχόμενον, δυστόχαστον, καὶ τελέως ἀναιτιολόγητον ὑπάρχει<ν>*[88] *κατὰ τὰς ἰδιότητας· τοῦτο δ' ἐπὶ τῶν θανασίμων φαρμάκων καὶ τῶν ἰοβόλων ζώων εἰωθὸς ἀποβαίνειν. τὸ μέντοι*

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[84] Touwaide (1992: 331-3).

[85] Touwaide (1992: 332).

[86] Touwaide (1992: 292n.12): "Mis un réexamen de la question nous a conduit à penser que notre traité est independent de celui de Philoumenos, utilisant peut être plus probablement une même source que celui-ci ou qu'un des modèles de celui-ci, source que dans l'état actuel de nos travaux, il est encore trop tôt pour identifier, quoique dans des *loca similia* des deux texts, le nom d'*Apollônius* apparaisse chez Philoumenos …" On Apollonius Mys see von Staden (1989: 540-54).

[87] *seccluserim*. *τυγχάνει ἀναλογητικῆς* creates hiatus, which Ps.-Dioscorides avoids. I suggest that a scribe mistakenly introduced *τυγχάνει* to account for the genitives. De Lacy's (1981: 52-55) discussion of hiatus in Galen includes the dipthongs *-οι, -αι, -ει* among examples of questionably allowable hiatus. But the examples he cites use hiatus to connect syntactically joined elements. Here *τυγχάνει* has dropped in among the elements of a genitive absolute. For this reason *τυγχάνει* ought to be suspected.

[88] *inservi*. This sentence and the next ought to be in indirect discourse, as befits the claim of the Empiricist that Ps.-Dioscorides will reject. According to van der Eijk's (2000: 1.286) apparatus, manuscript M reads *ὑπάρχειν*, which all subsequent editors (including van der Eijk) reject.

> εὔχρηστον εἰς τὰ ἔργα καὶ τὸ παρέχον τὰς τοῦ θεραπεύειν ἀφορμὰς, οὔτ' ἀκαταληπτόν ἐστιν, οὐτ' ἀναιτιολόγητον· καὶ μᾶλλόν τις ὁρμώμενος ἀπ' αὐτοῦ, πίστιν καὶ παρρησίαν ἔχειν διεβεβαιώσατο περὶ τῆς καταλήψεως τῶν ἀδήλων·
>
> The most important point must be stated: that the parts of medicine ought not be divided by the conditions of the body, but reasoning about nature on each part of all parts individually ought to occur on account of semiotics, as we show in the appropriate place. Therefore more does not need to be said on these matters. But rather <one> thing must be noted in addition, namely what properties from venomous animals and from fatal drugs are called that-for-which-no-cause-can-be-assigned [ἀναιτιολόγητα]. For this reason aporia occurs when a *techne* chances to be empirical and analogistic, therefore reason is to be trusted in. For not even in only one case is this true, but – [they say] – the superfluous is always that presenting no use to some treatment, is hard to hit upon, and no cause can be completely assigned in its individual properties; this [they say] often happens in fatal drugs and venomous animals. Surely[89] what is useful for work and offers starting point for therapy is neither ungraspable nor without cause. Rather, starting from it would confirm how to have expectation and freedom [to speak] about the understanding of the hidden things [ἀδήλων].[90]

Ps.-Dioscorides entered into the Hellenistic debate about causality as a full-throated Rationalist, punning on the Empiricists' point of rejection of reason. Where the Empiricists treat experience with confidence, *pistis*, Ps.-Dioscorides claimed that when *iatrike* becomes empirical, ὁ λόγος πεπίστευται "reason is to be trusted in", so *logos* becomes worthy of *pistis*. Ps.-Dioscorides continued with the Empiricists' claim: the superfluous knowledge of hidden things[91] offers no use to practical medicine, is difficult to achieve, and no cause regarding the individual properties of its substances can be assigned, such as happen in fatal drugs and venomous animals.

The key term in this passage is ἀναιτιολόγητον, which LSJ defines as "for which no cause can be assigned."[92] This adjective occurs rarely, only in 5 authors in the TLG corpus: Ps.-Dioscorides, Bolus (physician of 2nd/3rd CE), Alexander of Aphrodisias (*fl.* 3rd

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[89] I see in μέντοι a progressing to a new argument, Ps.-Dioscorides' argument against the Empiricist claims he has been listing. See Denniston (1950: 407), μέντοι 3.ii.

[90] [Dioscorides] *de iis, qui virus ejaculantur, animalibus* 26.46-48 K. My translation differs in many points from van der Eijk (2000: 1.287) = Diocles fr. 177 vdE.

[91] The term superfluous, τὸ παρέλκον, in Ps.-Dioscorides' argument corresponds to the superfluous, *superuacuam*, in Celsus' description of Empiricist doctrine, Celsus *Praef.* 36.

[92] LSJ *s.v.*

CE), Claudius Ptolemy (*fl.* 150 CE), and Eustathius (*fl.* 11th CE) who quotes Alexander. Excluding Eustathius, the word only occurs in authors of the 2nd and 3rd centuries CE. (It is perhaps noteworthy that the word does not appear anywhere in the extant corpus of Galen, who was active at this time and very interested in causality.[93]) Ps.-Dioscorides' use of the rare and chronologically defined term ἀναιτιολόγητον would suggest that *On Venomous Animals* dates to 2nd – 3rd centuries CE. Alexander, in a passage on causality in *De fato*, defines it: "The cause of these things [sc. of magic spells] is agreed by all to be unclear, wherefore they call them ἀναιτιολόγητα."[94] That is to say, there is some cause recognized for the action of magic, but no human knowledge can determine what it is. In Ps.-Dioscorides, the Empiricist claimed that even the causes of ἰδιότητες, specific properties themselves, are beyond human causal knowledge. In the case of drugs and venoms, the specific properties must be from the *pharmaka* themselves.[95] The Empiricist denies that knowledge of the hidden compounds in *pharmaka* can predict their effect in a chain of causality crossing the boundary between hidden and evident causes. Thus Ps.-Dioscorides uses the term ἀναιτιολόγητον in a similar manner to Alexander of Aphrodisias. For Ps.-Dioscorides' Empiricist the term ἀναιτιολόγητα recognized the epistemological conditions which confront any study of specific causality, the inability to cross from hidden to evident.

Ps.-Dioscorides rejected the Empiricist claim that pharmacological properties do not signify the causal chain passing from hidden to evident causes and that knowledge of these causes is superfluous for medicine. In particular, Ps.-Dioscorides fastens onto the notion of a starting point in medicinal therapy and treatment, ἀφορμαί. It seems as if Ps.-Dioscorides is taking Empiricist tropes and inverting them. The Empiricists emphasized therapy, so Ps.-Dioscorides argued that knowing the individual characteristics of drugs is a good starting point for therapy. These starting points can lead us to speak clearly and freely about ἄδηλα "hidden things". Whereas in discussion of the interior of the body

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[93] A TLG search for the search string ἀναιτιολόγητ* in the Galenic corpus yields no hits.

[94] Alex. *de Fato* 174.24 τούτων γὰρ ὁμολογεῖται μὲν ὑπὸ πάντων ἄδηλος εἶναι ἡ αἰτία, διὸ καὶ ἀναιτιολόγητα λέγουσιν αὐτά.

[95] Compare the above quoted passage from Ps.-Dioscorides παρασημειωτέον, ὅτι καλεῖται μὲν ἀναιτιολόγητα τὰ ἀπὸ τῶν ἰοβόλων ζώων καὶ τὰ ἀπὸ τῶν θανασίμων συμβαίνοντα φαρμάκων.

ἄδηλα might be the situation and function of the internal organs, ἄδηλα in pharmacology are the functions of the drugs themselves: the very chain of causality the Empiricists denied could be traced across the divide from evident to hidden causes.

Ps.-Dioscorides continued making his argument against the Empiricists by quoting from the works of Diocles and Erasistratus, specificially those works dealing with causality and pharmacology. His summary of Erasistratus pays particular attention to genus: "First they are not ungraspable in genus: because there is a property destructive and variable of the underlying substrates and of these in genus, [Erasistratus] does *not* describe a therapy by species, through which these things are counteracted and accomplished."[96] Ps.-Dioscorides stated that Erasistratus classed drugs by the properties of their genus alone, not by species, since there was some power common to all species of the genus. In the earlier discussion in 4.2.2 of transition from the similar, in which aloe, copper flakes, and an apple are astringent, Galen's Empiricist refused to consider all astringents drugs as a class on the *a posteriori* basis that not all are equally effective in different sorts of diseases: aloe, for example, is astringent in one case but not in another. By contrast, the Rationalist Ps.-Dioscorides was inclined to treat pharmacological properties at the most general level, because there is a φθαρτικὴ καὶ τῶν ὑποκειμένων ἀλλοιωτικὴ [sc. δύναμις] "destructive and variable property of the substrates" which is

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[96] The entire quotation of Erasistratus is very puzzling and it seems as if there are several lacunae in the text. The section translated above reads πρῶτον μὲν κατὰ γένος οὐκ ἀκατάληπτά εἰσιν· ὅτι μὲν γὰρ δύναμις ὑπάρχει φθαρτικὴ καὶ τῶν ὑποκειμένων ἀλλοιωτικὴ, καὶ τούτων κατὰ γένος, οὐ μὴν κατ' εἶδος ὑπογράφει θεραπείαν, δι' ἧς ταῦτα ἀμβλυντέον καὶ κατεργαστέον [Dioscorides] *de iis, qui virus ejaculantur, animalibus* 26.49 K = Empiricist fr. 25 D = Erasistratus fr. 35 Ga, who prints a different text. Garofolo (1988: 72): "Rilevante [to the Arabic translation of this passage] è l'omissione del titolo dell'opera περὶ αἰτιῶν, in accordo con il Laurentianus [MS]. Il solo empirico noto che quadra con l'epocha di Erasistrato è Philinos (Sprengel); ma il termine può designare i medici che rifiutano la teoria, senza formare perciò un movimento." Garofolo does not say which work of Erasistratus this text might come from if the title περὶ αἰτιῶν is rejected. But Wellman's index scriptorum (1908: 71) suggests that the fragments of Erasistratus in the extant excerpts of Philumenus might have come from Erasistratus' book περὶ δυνάμεων καὶ θανασίμων. Touwaide's (1992) argument that Philumenus and Ps.-Dioscorides share a common source instead of Ps.-Dioscorides depending directly on Philumenus therefore suggests that this quotation from Erasistratus might come from περὶ δυνάμεων καὶ θανασίμων instead of an otherwise unattested book περὶ αἰτιῶν. Garofolo (1988: 160-64) collects the fragments of Erasistratus' περὶ δυνάμεων καὶ θανασίμων but the only source to provide explicit evidence of the name of Erasistratus' book is Ps.-Dioscorides. It would be strange if Ps.-Dioscorides knew Erasistratus' περὶ δυνάμεων καὶ θανασίμων but invented a text περὶ αἰτιῶν for this passage. As above, it is simply enough that Ps.-Dioscorides reflects the vocabulary and attitudes of a Hellenistic source, even if *Quellenforschung* cannot determine whether Erasistratus is the true basis of Ps.-Dioscorides.

relevant when dealing with venomous animals and fatal drugs. Ps.-Dioscorides' Rationalist argument against the Empiricists centers around causality and theories of category: if ἄδηλα led to similar effects, then they must have a similar property. It is knowledge of these classes of pharmacological ἄδηλα, the function of their genus, which Ps.-Dioscorides regarded as essential medical knowledge of pharmacology; knowledge of classes and their functions therefore provide the starting points to therapy. In this way therapy, the Empiricist concern, is seen to depend on knowledge about causality, classes of ἄδηλα.

4.3.4 Surgery

If some Rationalists like Ps.-Dioscorides argued against Empiricist teaching by emphasizing the indicative semiotics of the causal chain, other Rationalists argued differently. Apollonius of Citium's *Treatise on Hippocrates' On Joints* preserves a lengthy quotation from the Herophilean doctor Hegetor. Apollonius provides a *terminus ante quem* for Hegetor's dating, implying that Hegetor worked either in the 2nd or early 1st century BCE.[97]

> *θαυμάζω δὲ ἐπὶ τοῖς τὴν πολυθρύλητον ἀνατομὴν ἐναγκαλιζομένοις Ἡροφιλείοις, μάλιστα δὲ ἐπὶ Ἡγήτορι. ἐν γὰρ τῷ Περὶ αἰτιῶν περὶ μηροῦ ἐξαρθρήσεως οὕτως ἐμέμνητο τὰ ὑποτεταγμένα διασαφῶν· "διὰ τί δὲ οὐκ ἐπιβάλλονται ζητεῖν ἄλλην τινὰ ἐμβολὴν τῆς τοῦ μηροῦ κεφαλῆς παρὰ τὰς νυνὶ καταπεπτωκυίας, καθ' ἣν, ὅταν ἐκπέσῃ, ἐμβληθεῖσα μένει, οἱ μόνον αὐτῇ τῇ τριβῇ προσχρώμενοι, θεωροῦντες ἐκ τοῦ ἀνὰ λόγον ἐμβαλλόμενα καὶ μένοντα τήν τε κάτω σιαγόνα καὶ τὴν τοῦ βραχίονος κεφαλήν, ἔτι δὲ ἀγκῶνα καὶ γόνυ καὶ τῶν δακτύλων ἕκαστον καὶ σχεδὸν τὰ πλεῖστα τῶν εἰθισμένων ἐκπίπτειν ἄρθρων; οὐδὲν γὰρ ἔχοντες αὐτοῖς ἐπιλογίσασθαι, διὰ τί ποτε μόνον τοῦτο τῶν ἄρθρων ἐκπεσὸν καὶ πάλιν ἐμβληθὲν οὐ δύναται μένειν, τῷ δὲ πλεονάκις ἐπὶ τῶν λοιπῶν ἄρθρων γινομένῳ προσχρησάμενοι ἤξουσιν κατά τι πιθανὸν ἐπὶ τὸ νομίσαι, μή ποτε ὑπάρχῃ βελτίων ἐμβολή, καθ' ἣν δυνήσεται μένειν τὸ ἄρθρον, ἐχόμενοι τοῦ κατὰ τὸ πλεῖστον ἐπὶ τῶν λοιπῶν συμβαίνοντος. εἰ δὲ ἐπενόησαν τὴν αἰτίαν ἐξ ἀνατομῆς, διότι συμβέβηκεν ἐκ τῆς κεφαλῆς τοῦ μηροῦ νεῦρον ἐκπεφυκέναι, ὃ ἐμφύεται εἰς μέσην τὴν κοτύλην· οὗ μένοντος μὲν ἀδύνατόν ἐστιν ἐκπεσεῖν τὸν μηρόν, διασπασθὲν δὲ οὐκ ἐνδέχεται σύμφυσιν λαβεῖν, μὴ γεγενημένης δὲ τῆς συμφύσεως ἀδυνατεῖ πάλιν κατὰ χώραν μένειν τὸ ἄρθρον, ὥστε φανερᾶς τῆς αἰτίας γενομένης ἀποστῆναι καθόλου τοῦ ἐμβάλλειν ἐκπεσόντα μηρὸν καὶ μὴ κατακολουθεῖν ἀδυνάτοις ἐπιβολαῖς."*

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[97] Von Staden (1989: 513) "About the date of Hegetor we cannot be sure." Von Staden does not offer a date, but Frede's (1987) argument about Heraclides of Tarentum's response to Hegetor = Empiricist fr. 175 D (explored above in chapter 4.1.1) makes it likely that both Heraclides and Apollonius were responding to a recent author or a near contemporary.

> I am amazed at the Herophileans who embrace the notorious dissection, especially Hegetor. For in *On Causes* he speaks thus about the dislocation of the thigh bone making clear the subject at hand: "And why do they not try to seek some other setting of the head of the thigh bone besides those I've rejected, so that whenever it dislocates it remains set in place? Those who only employ experience itself perceive by an analogy <joints> that are set in and remain in place, [I mean] the lower jawbone and the head of the arm and moreover the elbow and knee and each of the fingers and nearly the majority of joints which usually dislocate. For they can't explain to themselves why this joint alone, when dislocated and again set, cannot remain in place. And when they apply that-which-has-happened-frequently in the case of the remaining joints, they will come to think it reasonable that there will not be a better setting so that the joint will remain in place, because they hold to what happens for the most part in the remaining joints. But [they would know] if they considered the cause from anatomy, that the ligament happens to process out of the head of the thigh bone which is inserted into the middle of the joint socket. When it remains, it is impossible for the thigh bone to dislocate; but when it is sundered it cannot be fused. And since a fusion has not happened, it is again impossible for the joint to remain in place. Therefore, once the cause is clear, avoid in general setting a dislocated thigh and do not proceed in impossible attempts."[98]

Hegetor, like Ps.-Dioscorides, mocked the Empiricists, referring to them never in name but only by the first element of the Empiricist tripod: *οἱ μόνον αὐτῇ τῇ τριβῇ προσχρώμενοι* "those who only employ experience itself". He claimed that knowledge of anatomy shows that it is impossible to reset a dislocated hip, although the joint of the hip is similar to "the elbow and knee and each of the fingers." The Empiricists, Hegetor implied, transitioned from similarity to similarity based on the joint as a shared part; but they had no understanding of why analogical reasoning does not work in the case of the hip joint. Hegetor's criticism of the Empiricists deliberately ignored their focus on individual circumstances: it is not the nature of the thing that Empiricists use in transition from the similar but rather similarity in location and effect, as was shown in 4.2.2. Hegetor's exaggerations of the Empiricists' methodologies add rhetorical lustre to his polemic.

For his own part Hegetor believed in the usefulness of anatomy to medicine. He

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[98] Hegetor *apud* Apollonius of Citium *In Hipp. Art. Comm.* 3.23, 78.24-80.14 Kollesch and Kudlien (1965) = Empiricist fr. 276 D = Hegetor fr. 3 vS.

argued that it is in fact impossible to reset a dislocated hip due to the processes of the femur bone. He claimed that the ligament connecting the femur to the hip joint will normally prevent dislocation; but if the ligament is severed, the hip cannot be reset because the ligament will not fuse like bone. Everything in Hegetor's discussion revolves around the existence and position of the ligament connecting femur and hip socket. Since this ligament does not exist in other joints – like the hands and fingers – doctors had better understand its role in the dislocation of the hip. In contrast to Ps.-Dioscorides who focuses on semiotics of *pharmaka* as a class, Hegetor ignores semiotics and causality to open up the body directly. The problem with the Empiricists is that they did not know about bodily interiority and tried to avoid it, Hegetor claimed, whereas what medicine needs is to consider anatomy.

I find it difficult to decide whether Apollonius' *τὴν πολυθρύλητον ἀνατομὴν* ought to be translated as "the notorious anatomy" or "the notorious dissection," which I have chosen.[99] Whether Hegetor practiced dissection in imitation of Herophilus, *ἀνατομὴν* earns Apollonius' opprobrium for its active investigation into the interior parts of the body. It is tempting to speculate that Hegetor's insistence on *ἀνατομὴν*, the cited book title *περὶ αἰτιῶν*, and Hegetor's assumed opponents, the Empiricists, imply that Hegetor's book was a ideological polemic about how dissection contributed direct knowledge to causes of wounds and injuries, such as hip dislocation.

The polemical tone Hegetor adopts shows the asymmetry of debate between Hellenistic sects. By exaggerating and ridiculing Empiricist methodological principles, Hegetor the Rationalist emphasized knowledge in his critique.[100] Still, Hegetor's insistance that a dislocated hip cannot be reset is a triumph of reasoning but is discomforting to a patient. His conclusion, "avoid in general setting a dislocated thigh

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[99] Kollesch and Kudlien (1965: 79) translate "Anatomie" but *ἀνατομή* can equally refer to dissection, as I have translated.

[100] Von Staden (1989: 513): "His allusion, in part ironic, to the Empiricists' facile recourse to analogy, to their anti-aetiological stance and their consequent failure to discover the causes of particular disorders, to their use of 'what happens more frequently' (i.e. their use of statistical differentiation at the expense of causal theory), and his own insistence that only an understanding of causes (in this case based on anatomy) could resolve certain apparently insoluble problems which beset the practising surgeon – all these are clear reveberations of this protracted Alexandrian feud between Empiricists and 'rationalists' such as the Herophileans."

and do not proceed in impossible attempts," is a warning to the physician to not practice what is impossible. The apparent lack of concern for the patient in this warning leaves a cultural opening for Empiricist rebuttal.

As was said in 4.1, almost no Empiricist works are extant except for one, Apollonius of Citium's *fl.* 90-70 BCE[101] *Treatise on Hippocrates' On Joints.*[102] Although it is not an anticategoretic treatise, Apollonius does occasionally take sides in the debate between Hellenistic schools. Immediately after his quotation of Hegetor, Apollonius attempts a rebuttal.

> ἐν τούτοις ὁ Ἡγήτωρ οὐ μόνον πεπλάνηται, ἀλλὰ καὶ τοὺς φιλιατροῦντας ὅσον ἐφ' ἑαυτῷ διέστρεφεν· ἔτι δὲ καὶ τῶν ὑπὸ Ἱπποκράτους ἐν τῷ Περὶ ἄρθρων εἰρημένων οὐδαμῶς κεκράτηκεν, ἀλλὰ καὶ ἀπὸ ἀνομολόγων τὴν ἐπιχείρησιν ἐν τοῖς προκειμένοις εὐηθέστερον συνίσταται· ἵνα δὲ μὴ πολυγραφῶμεν, κεφαλαιώδεις τὰς πρὸς αὐτὸν ὑπομνήσεις ποιησόμεθα. οἱ γὰρ αὐτῇ μόνῃ τῇ τριβῇ προσχρώμενοι, μένοντες ἐπὶ τῶν ἐμπείρως παρατετηρημένων, οὔθ' ὁμολογήσουσιν, ὅτι καθόλου μηρὸς ἐξαρθρήσας καταρτισθεὶς πάλιν ἐκπίπτει, οὔτε πάλιν ἐμβολὴν παρήσονται, ποτὲ τοῦ προκειμένου μὴ κρατηθέντος. εἰ δὲ τοῦτο ἀληθές ἐστιν, ὅπερ καὶ βούλεται, οὐδ' ἂν οὕτως ἐγενήθησαν οἱ τῇ παρατηρήσει συγχρώμενοι, ἀλλ' ὃν τρόπον καὶ τὰ ἐπὶ τῶν <λοιπῶν> ἄρθρων αὐτοῖς τεθεώρηται, οὕτως καὶ τὰ ἐπὶ μηροῦ ἰδίως παρακολουθοῦντα κατειλῆφθαι πιθανόν ἐστιν, ὥστε μὴ βουλεύεσθαι <αὐ>τοὺς τῇ γνώμῃ ζητοῦντας βελτίονα ἐμβολήν, μένειν δὲ ἐπὶ τοῦ θεωρηθέντος ἐμπείρως. ὅτι δὲ μηρὸς ἐξαρθρήσας καὶ ἐντεθεὶς πάλιν κατ' ἀνάγκην ἐκπίπτει, οὔτε τὸ γινόμενον οὔθ' ἡ τῶν ἀρχαίων ἱστορία τοῦτο περιέχει. εἰ γάρ τινι καὶ ἄλλῳ, περὶ τῶν ἄρθρων ἐπιμελὲς γέγονεν καὶ Ἱπποκράτει· οὕτως δὲ φιλαλήθης ὑπάρχων καὶ τὰ ἐπὶ τῶν λοιπῶν ἰδιώματα διασαφῶν οὐδὲν περὶ μηροῦ δεδήλωκεν, ὅτι οὐκ ἂν δύναιτο καθόλου κρατεῖσθαι, ἀλλ' ἐκ τῶν ἐναντίων ἐκπεπνευμάτωκέν πως ἐπὶ τῶν τοῦ μηροῦ ἐμβολῶν, ὥστε καὶ ὀργανικὴν ἐπίνοιαν ποιήσασθαι.

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[101] The dating of Apollonius is vexing. He refers to Hegetor in the body of the treatise, as we have seen, but his introduction provides the best evidence of his time frame: here he refers to a *βασιλεῦ Πτολεμαῖε* who ordered him to write the text. From the rough date of Apollonius' language this Ptolemy is one of four possibilities from two generations: of the first generation Ptolemy IX Lathyrus or Ptolemy X Alexander I (both variously ruling 107-81 BCE); of the second generation Ptolemy XII Auletes, who began ruling in 80 BCE, or Auletes' brother Ptolemy of Cyprus who ruled 81-58 BCE. In his introduction Apollonius also mentions his teacher, Zopyrus of Alexandria, and a witness of Zopyrus' competence, Posidonius. Kudlien (1962: 427) believed that this Posidonius was Posidonius of Apamea, the Stoic, but Kidd (1988: 92-93) denies this. Deichgräber (1965: 206) gives Apollonius a *floruit* of 70 BCE but Nutton (2004: 142) gives a more conservative *floruit* of 90 BCE. Schoene's (1896: xxiv-xxv) Teubner edition of Apollonius argues for a date between 81-58 BCE at the court of Ptolemy of Cyprus. I incline toward the traditional date c. 70 BCE but cannot decide whether Apollonius' dedicatee is Ptolemy XII Auletes or Ptolemy of Cyprus.

[102] See Deichgräber (1965: 206-9) for the few other fragments and testimonia about Apollonius beyond the *Commentary*. I translate the title *πραγματεία* with "treatise" because, as von Staden (2006: 15.n3) points out, Apollonius' treatise is not really a commentary in the later lemmatized sense of Galen's Hippocratic commentaries, for which the usual titles are *ἐξηγήσεις* or *ὑπομνήματα*.

In these things Hegetor not only raves but also has confused friends of medicine[103] as much as he is able. Still he has in no way overcome what was said by Hippocrates in *On Joints*, but constructs his dissection in the previous passage rather sillily from un-agreed-upon points. In order that we not write too much, we will make summary notes against him. For those employing only experience itself, remaining on what has been observed empirically, neither agree that in

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[103] This is an important passage for the question of patronage and court science. For φιλιατρέω LSJ *s.v.* offers "to be an amateur doctor", simply a wrong translation for this passage; Kollesch and Kudlien (1965: 81) are closer when they translate "die an der Medizin Interessierten"; Smith (1979: 213) translates "friends of medicine" correctly. We should understand in this word an allusion to Apollonius' opening letter to Ptolemy, θεωρῶ φιλιάτρως διακείμενόν σε, βασιλεῦ Πτολεμαῖε κτλ. *I see that you are disposed in a way friendly to medicine, King Ptolemy etc*. Apoll. *In Hipp. Art. Comm.* 1.1, 10.1 Kollesch and Kudlien (1965). Ptolemy is a friend of medicine; he is only interested in it insofar as he is Apollonius' patron. The compound φιλιατρέω is paralleled by the nominal phrase τοῖς οἰκείοις τῶν μαθημάτων *friends of mathematics* in Archimedes *On the Sphere and Cylinder* 4.18-19 Heiberg. Netz's (2004a: 34) commentary on the Archimedes passage is instructive: "There is another, much more peripheral readership: '…those who are friendly toward mathematics,' and it is with them that Archimedes say that he has decided to 'share.' In other words, Dositheus [Archimedes' correspondent] is one of the 'friends.' He is no mathematician according to Archimedes' standards." The point in both the Apollonius and Archimedes passages is the rhetorical move of the protagonist within the group presenting 'insider information' to a friend outside the group. By communicating this insider information publicly, the scientific author both claims true understanding of the information of the scientific field and offers himself as a guide to the field for the lay public: he is poised to mediate appropriately between inside and outside.

But in the context of Apollonius' treatise the lay public does not exist: the person outside medicine to whom Apollonius is communicating his information is his patron, King Ptolemy. Which royal Ptolemy is meant remains unclear; see footnote 101. (The epithet βασιλεύς is appropriate for both kings and princes of this period; see Fraser (1972: 2.586-87.n239) with reference to Pfeiffer's *Kallimachosstudien*.) Apollonius turns the scientific dispute between Herophileans and Empiricists into a social issue: the Herophileans, like Hegetor, will confuse and lead astray (διέστρεφεν) patrons who sponsor medicine (τοὺς φιλιατροῦντας), like Ptolemy. (Whether Ptolemy managed to read three books into a very technical and boring work illustrated with pictures to understand Apollonius' social strategy in this passage is a question better left to historical psychologists.) In the dichotomy of social relationships between the scientific inside and royal outside, Apollonius is internally trying to gain traction in his dispute with the Herophileans by bringing Ptolemy's superior social standing to bear against Hegetor and the Herophileans. For the royal patrons on the outside, Apollonius' aim was to place the Herophileans outside the 'real' scientific community and thereby to denigrate the social standing of the Herophileans as possible clients for royal patrons. Nonetheless Apollonius' strategy was unsuccessful: a younger contemporary of Apollonius, Dioscurides Phacas *fl.* 75-31 BCE, a Herophilean, became the court physician to Ptolemy XII Auletes and his children, Ptolemy XIII and Cleopatra VII. On Dioscurides Phacas see von Staden (1989: 519-522).

It is unclear to what extent we can imagine Ptolemy 'judging' the dispute between Apollonius and Hegetor as exponents of the Empiricists and Herophileans. Biagioli's (1993: 73-90) remarks on the attitude of Baroque Italian patrons toward their scientific champions suggest that patrons aimed less for a finality to debate than for the notion of aristocratic 'good sport', with appropriate give and take in the manner of chivalric duels. Lloyd's work stressing the variety of opinions held by Greek scientists (1979, 1983, 1987, 1990) suggests that there is a corresponding lack of closure to debate in Greek science. Yet Galileo's patrons, the Medici, and other 16th-17th century CE Italian aristocratics are caught up in Baroque codes of comportment, an attitude not applicable to the Hellenistic monarchs of 323-31 BCE. To push the analysis of Apollonius' patronage further requires more thinking about the values of (in)dependence and tradition and about the status of craftspeople and entertainers at Hellenistic courts.

> general a thigh dislocated and set right again dislocates, nor disregard a setting again when the previous did not take. If what he wants were true, those using observation could not be [as they are] but, in the same way they understood the situation in the case of the remaining joints, so too is it reasonable that particular consequences in the case of the thigh bone be understood. Therefore those who seek by reason do not want a better setting to be understood but remain in their practice on the theorized point. Neither the fact nor the report of the ancients presents this [claim], that the thigh, when dislocated and set in, falls out again by necessity. For if it was known to this one <person> or another, it would be a concern for Hippocrates too. And being such a lover of truth and making clear his particular views on remaining subjects he has explained about the thigh that in no way one could not overcome it in general, but contrawise he was [so] inspired somehow in the case of settings of the thigh bone that he made an instrumental solution.[104]

Apollonius stood firmly on Empiricist ground and reiterated the need for experience in medicine. The text continually emphasizes Empiricist ἐμπειρία: ἐμπείρως "empirically", παρατήρησις "experience". Apollonius refused to consider Hegetor's speculative claim that there is a ligament in the hip socket which, when cut, prevents resetting of the joint.

Furthermore, Apollonius rejected Hegetor's view because theoretical views failed to improve treatment. It is interesting to see an Empiricist making an argument about progress: unlike the Rationalist promise of medical progress grounded in knowledge of *physis*, Apollonius' vision of progress is improved therapy. In the rhetoric of scientific progress Empiricism fastened on therapy, Rationalism on knowledge: the debate between sects was asymmetrical even in their views of scientific progress. The Rationalists, Apollonius insisted, "do not want a better setting to be understood but remain in their practice on the theorized point." A better setting of the dislocated femur is an improved therapy for the patient but the denial of the theoretical possibility offers no therapeutic progress.

In addition to the expected Empiricist focus on experience and therapy, Apollonius repeatedly invoked Hippocrates' views and observations against Hegetor. He

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[104] Apollonius of Citium *In Hipp. Art. Comm.* 3.23, 80.14-82.6 Kollesch and Kudlien (1965) = Empiricist fr. 276 D. I understand Kollesch and Kudlien's translation of the phrase ὅτι οὐκ ἂν δύναιτο καθόλου κρατεῖσθαι "daß man vielleicht seiner nicht völlig Herr werden könne" to mean that the patient regains use of his formerly dislocated limb; I think this is a wrong translation. Compare also the translation of Smith (1979: 213-14).

used Empiricist language: *ἡ τῶν ἀρχαίων ἱστορία* "the report of the ancients" where *ἱστορία* "report", the second leg of the tripod, refers to the recorded observations of earlier doctors. Frede (1987) suggests that Apollonius' insistence that a dislocated hip does in fact reset may be drawn from the reports of his earlier contemporary, Heraclides of Tarentum, who had also taken issue with Hegetor's views, as we have seen in 4.1.1 above.[105] (Heraclides listed seven previous physicians, including Hippocrates, who recorded their *ἱστορία* that they had successfully reset a dislocated hip joint.) Apollonius said that Hippocrates did not record that a dislocated hip joint could not be reset, as Hegetor claimed. Smith (1979) has memorably doubted Apollonius' Empiricism: "Apollonius may have been an Empiric, but more likely he stepped forth as a Hippocratean."[106] While it is true that Apollonius nowhere identifies himself as an Empiricist, there are many indications that he was an Empiricist and, simultaneously, a Hippocratean. Apollonius continuously invoked the contrast between Rationalists – *<αὐ>τοὺς τῇ γνώμῃ ζητοῦντας* "those who seek by reason" – and Empiricists – *οἱ γὰρ αὐτῇ μόνῃ τῇ τριβῇ προσχρώμενοι* "those employing only experience itself", *οἱ τῇ παρατηρήσει συγχρώμενοι* "those using observation". Apollonius aligned Hippocrates with the Empiricists against the Rationalists, for Hippocrates has recognized that the dislocated femur can be reset and even devised an instrument to accomplish that. By aligning Hippocrates with the Empiricists, Apollonius explicitly brought a respected ancient authority over to the Empiricist side in the dispute between medical schools and thereby aligned the Empiricist vision of medicine with Hippocrates. These are ideological moves appropriate to a debate between medical sects.

A philological element in Hippocrates' text has become a social dispute in Apollonius' hands. Hippocrates was not simply a traditional authority for Apollonius: he was also an Empiricist authority and, perhaps, an early Empiricist. Galen recorded that some Empiricist doctors did claim that Hippocrates was an Empiricist.[107] In 4.2.3 I

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[105] Frede (1987: 94).

[106] Smith (1979: 215).

[107] Gal. *In Hipp. Art. Comm.* 18A.524 *ἐν ᾧ* [Galen's commentary on Hippocrates' *Anatomy*] *γνώσῃ τὴν ἀναισχυντίαν τῶν ἐμπειρικῶν ἰατρῶν τολμησάντων Ἱπποκράτην καλεῖν ἐμπειρικόν.* = Empiricist fr. 310 D.

argued that Empiricism shared elements reminiscent of 5th century BCE intellectualism with its focus on a re-authoriziation of the role of caregiver, a re-authorizing of the primacy of vision in knowledge, a reassertion of the uniqueness of the patient and his circumstances. Since Empiricism was as much a cultural argument about the role of the doctor in medicine as an intellectual movement about the manner by which a doctor advance to knowledge, it is not surprising that Empiricists would try to appropriate Hippocrates, the great doctor of 5th century BCE science. The Empiricist claim that Hippocrates was an Empiricist is a serious claim, not because it is verifiably true or false,[108] but because of the cultural argument the Empiricists were thereby making against the Rationalists. The Empiricists argued that physicians ought to be healers and caregivers, just like Hippocrates was; and Hippocrates established medicine.

4.3.5 Sects, Symbols, and Motives: The ἱστορία τῶν χαρακτήρων Reconsidered

There is a further example that shows how a philological argument about Hippocratic texts became a social controversy between sects in the asymmetry of Empiricist and Rationalist sect arguments, respectively, about the doctor's role as a caregiver and methodological knowledge of *physis*: the philological controversy called the ἱστορία τῶν χαρακτήρων demonstrates the Empiricist appropriation of Hippocrates as a proto-Empiricist.

Near the end of the third or the beginning of the second century BCE manuscripts of Hippocrates' *Epidemics* III appeared in circulation that had strange markings in them (χαρακτῆρες), such as ΠΔΕΗΘ, at the end of case histories.[109] The markings were a combination of normal letters and symbols perhaps representing combinations of letters. A controversy almost immediately developed as to what they meant and whether they were original to the text or interpolations; the Herophileans Zeno *fl.* 175 BCE,[110] Zeno's

[108] The *Hippocratic Corpus* has many voices. See Smith (1979: 204-14) for the argument that Hippocrates can neither be shown to be a Rationalist nor Empiricist.
[109] Scholarship on the ἱστορία τῶν χαρακτήρων includes Fraser (1972: 1.376-77), Smith (1979: 199-202), and von Staden (2006) all with reference to further bibliography.
[110] For an overview and fragment collection see von Staden (1989: 501-505).

presumably Herophilean followers,[111] and Heraclides of Erythrae *fl.* 25 BCE[112] and the Empiricists Zeuxis *fl.* 200 BCE,[113] Apollonius the Empiricist *fl.* 175 BCE,[114] Apollonius Byblas *fl.* 150 BCE,[115] and Heraclides of Tarentum *fl.* 75 BCE all took part. The fracas finally ended when the Herophilean Heraclides of Erythrae (*fl.* 25 BCE) agreed with the Empiricists that the symbols were inauthentic: the fact that the controversy only ended when Rationalists agreed with the Empiricists shows the ideological basis to the dispute.[116] What motivated the Empiricists to declare the symbols inauthentic? The positive self-fashioning of the Empiricist research program, shown in 4.2, stressed the legs of the Empiric tripod: ἐμπειρία "experience" and ἱστορία "research". Empiricist physicians use previous physicians' reports of their ἐμπειρία to supplement their own experience; thus Hippocratic texts offer ἱστορία to Empiricist physicians. The employment of previous records demands accurate reporting and transmission of previous records: if the accuracy of the text is in doubt, controversies about medical practice can suddenly become controversies about philological transcription and interpretation. I argue that the protracted dispute about the strange markings in the manuscripts of *Epidemics* III was such a case.

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[111] Galen credits Zeno with a literal army of followers but does not give their school affiliation. Since the early Empiricists attacked Zeno's views on the markings it seems safe to assume that the followers must have at least been Rationalists, if not strictly Herophileans. τῶν ἐκ τοῦ Ζηνωνείου στρατοπέδου Gal. *In Hipp. Lib. Epi. III. Comm. II.* 90 17A.625 K = 93.10 Wenkebach = Zeno fr. 6 vS.

[112] For an overview and fragment collection see von Staden (1989: 555-558).

[113] For an overview see von Staden (2006: 30-40); for the fragment collection see Deichgräber (1965: 209). Deichgräber dated Zeuxis' *floruit* to "um Christs Geburt", a date corrected by Kudlien (1972).

[114] For an overview and fragment collection see Deichgräber (1965: 171).

[115] For an overview and fragment collection see Deichgräber (1965: 172).

[116] Von Staden (2006) has drawn attention to the controversy in the context of Hippocratic lexicography in the 3rd and 2nd centuries BCE. He has stressed (2006: 45) that in the context of Hippocratic lexicography and exegesis Empiricist authors sometimes attack each other and defend Herophileans and vice versa, and that, comparatively speaking, Empiricist commentators rarely appropriate Hippocrates as a proto-Empiricist: "The rareness of such exegetical acts of 'empiricizing' Hippokrates, along with the Empiricists' frequent, overt agreement with the exegeses offered by the so-called 'rationalist' commentators, strongly cautions one against framing the history of Hellenistic Hippocratic commentaries mainly in terms of 'school rivalries.'" I take von Staden's point that a blanket assumption of Hippocratic exegesis in terms of either Rationalist or Empiricist is not justified, but I will argue that the dispute must be considered in terms of the two types of sectarian self-fashioning set in 4.1.2. A reading of the controversy of the markings (χαρακτῆρες) which focuses on the type of reading Empiricists gave to Hippocrates will accord with the positive picture of the Empiricist program from chapter 4.2.

Galen's commentary on *Epidemics* III contains the best account of the history of the markings (χαρακτῆρες). It is worth quoting *in extenso*:

> And now I will state the entire story of the markings, since this seems to my friends and comrades to be better all at once here. What I am going to say has been said by Zeuxis in the first book of his *Commentaries* on the book at hand. It would probably be better, just as I am accustomed to do in such circumstances, to send those wanting to know this history to that book, but since Zeuxis' commentaries, no longer circulating, are rare, on that account they thought it good that I detail these things making my beginning from Mnemon. Well some say that Mnemon, taking the third book of the Epidemics from the great library in Alexandria to read it, returned it after he interpolated in it those markings with black ink in equal letters. Some say that he had brought the interpolated book from Pamphylia, and they say that the king of Egypt at that time [viz. Ptolemy III Euergetes] was so very keen on books that he ordered even the books of all landing travelers to be brought to him and, after writing these on new sheets, he gave what had been written to their masters, whose books upon landing had been brought to him, and he placed what he had acquired into the libraries, and the title of these was *Those from the ships.* They say that one such thing was found, the third book of the *Epidemics* entitled *Those from the ships according to the corrector Mnemon of Side*. Some say that it was not entitled *according to the corrector* but simply the name *of Mnemon*, since the servants of the king gave the name of any of those landing with their books as a title to those books being set off in the storehouse. For they were not accustomed to bear them into the libraries, but rather to set them in some houses in heaps. [Galen next digresses to retell the story of Ptolemy Euergetes' acquisition of the Athenian state copies of the tragedies of Aeschylus, Sophocles, and Euripides to illustrate his bibliomania.] So Mnemon, either he himself acquired the book or taking it from the library interpolated it, appears to have done this for the sake of gain. For saying that he alone understood what the marks meant, earned payment for his interpretation of them. And if this is so, it is more reasonable that the book set off in the library had been prepared by him. For the business of interpretation would be much more worthy of belief, if some book of the royal library had the marks. It would be suspicious if he had brought the book from home. I would not hesitate to say even the proofs written by Heraclides of Tarentum and Heraclides of Erythrae that the marks were interpolated, if I did not think that this would be clear to those with sense and I hastened quickly to avoid such wordiness.[117]

Galen writes after the controversy has drawn to a close and seemingly fallen into oblivion, thanks to the judgment of Heraclides of Tarentum, the Empiricist, and

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[117] Galen *In Hipp. Lib. Epi. III Comm. II* 17A.605-608K = 78.27-80.19 Wenkebach = Empiricist fr. 343 D = Heraclides of Erythrae fr. 5 vS.

Heraclides of Erythrae, a Herophilean, that the markings were inauthentic. Zeuxis' book, likely a commentary on *Epidemics* III, preserved the best account of the genesis of the markings. According to this Empiricist, they came to Alexandria from a manuscript copy of a certain Mnemon, an obscure doctor Galen describes as "Pamphylian by birth, from the city of Side, of the sect of Cleophantes" (Erasistratus' brother).[118] As Galen retells Zeuxis' story, Alexandria at the time collected material from all travelers and copied it by royal order. In Galen's accusation Mnemon may have altered a library copy of the *Epidemics* in exchange for payment for interpretation.

Whatever their origins, the symbols found a defender of their claim to Hippocratic authenticity in the Herophilean Zeno (*fl.* 175BCE). Zeno wrote "no small book" about the markings. He apparently claimed that the markings served as mnemonic device for Hippocrates to remember each case history. Zeno understood each symbol as an acrostic representing a new word in a sentence summarizing the case at hand. Galen preserves an explanation of Zeno's interpretation of each type of letter and symbols of letter combinations.

> Well then he [Zeno] thinks, as I said, of all <letters> the pi having the line through the middle [i.e. Π] always means πιθανόν [it is reasonable]. And at the end either the letter υ appears written or θ, the one meaning ὑγεία [health], the other θάνατος [death], and before these the number of days in which the patient was sick or died. All the marks between these are via letters, which mean the first letters of the words, except for the delta marked-off below. What meaning each of these has, I will make clear. Therefore as I mentioned, in respect to those things written before the end of the marks, by which we said death or health was meant, means the number of days; as for the rest, however many between these and the beginning are written, I will make an account. The α seems to mean ἀποφθορά [destruction] or ἀπώλεια [destruction], the γ γόνον [seed] or γονοειδὲς οὖρον [seedy urine], the delta marked-off below (they call it marked-off whenever it has a perpendicular line below, just like ι, written in the following way Δ) either διάρροια [diarrhea] or διαχώρησις [evacuation] or in composition whatever emptying they want them to mean, the ε ἐποχή [restraint] or ἕδρα [location], the ζ ζήτημα [inquiry], the θ θάνατος [death], as was said before, the ι ἱδρῶς [sweat], the κ κρίσις [crisis] or κοιλιακὴ διάθεσις [colic disposition], the μ μανία [mania] or μήτρα [womb], the ν νεότης [youth] and νέκρωσις [necrosis], the ξ ξανθὴ χολή [yellow bile] and ξένον τι καὶ σπάνιον [something strange and rare] and ξυσμός [itching] and ξηρότης [dryness], the ο ὄδυναι [pains] or οὖρον [urine],

[118] Galen *In Hipp. Lib. Epi. III Comm. II* 17A.603K = 77.19-20 Wenkebach.

> (some say when it has the υ above, then it means urine itself, written as they are accustomed to write οὕτως [thus]), the π πλῆθος [amount] or πτύελος [spit] or πῦρ [fire] or πύρετος [fever] or πνεύμονος πάθος [affliction of the lung], the π having the ι in the middle of it, just as was said before, means πιθανόν [it is reasonable], the ῥ ῥύσις [flow] or ῥῖγος [cold], the σ σπασμός [spasm] or στομάχου πάθος [affliction of the gullet] or στόματος κάκωσις [affliction of the mouth], the τ τόκος [birth], the υ ὑγεία [health] or ὑποχόνδρον [the abdomen below the diaphragm], the φ φρενῖτις [phrenitis] or φθίσις [destruction], the χ χολή [bile] or χολῶδες [bilious], the ψ ψῦξις [chill], the ω ὠμότης [rawness].[119]

For Zeno the letter and symbol sequence consists of a single sentence meant to summarize the result of the case (restoration to health or death), the length of the disease before the result, and the cause of the disease. Each other letter which was not the number of days Zeno took to be an acrostic of a word representing various diseases, places on the body, and typical Hippocratic qualities. Each sequence of markings begins with the Π which Zeno took to represent the beginning of the indirect statement which summarized Hippocrates' views of the essentials of the case, πιθανόν "it is reasonable that". For example, *Epidemics* III.7 had the symbol sequence ΠΔΕΗΘ, which Zeno interpreted to stand for πιθανόν ἐστι τῶν διαχρουμένων ἐπισχεθέντων ὀγδοαίαν ἀποθανεῖν "It is

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[119] Galen *In Hipp. Lib. Epi. III Comm. II* 17A.611-613K = 82.15-83.13 Wenkebach. Von Staden (1989) does not record this passage among the fragments of Zeno, perhaps in accord with his editorial principles that only passages naming the author will be recorded. But I take the subject of ἡγεῖται to be Zeno because Galen has already explained that it is his system of explaining the marks that is at stake and that Zeno thought the pi with the extra vertical meant πιθανόν. Wenkebach's note *ad loc.* cites the previous passages in Galen's commentary: Zeno is Galen's subject in his lengthy explanation of the reading of the sequence ΠΔΕΗΘ at 17A.600K = 75.23 Wenkebach = Zeno fr. 5 vS. I see the ὡς ἔφην as Galen's reference to the earlier mention of Zeno and suggest including this passage among Zeno's fragments as Zeno fr. 5b vS. ἡγεῖται μὲν οὖν, ὡς ἔφην, ἁπάντων τὸ τὴν διὰ μέσου γραμμὴν ἔχον πεῖ, σημαῖνον ἀεὶ τὸ πιθανόν. τελευταῖον δ' ἤτοι τὸ υ γράμμα φαίνεται γεγραμμένον ἢ τὸ θ, τὸ μὲν ὑγείαν, τὸ δὲ θάνατον σημαῖνον, ἔμπροσθεν δ' αὐτῶν ὁ τῶν ἡμερῶν ἀριθμός, ἐν αἷς ἐνόσησεν ἢ ἀπέθανεν ὁ κάμνων. οἱ δ' ἐν τῷ μεταξὺ τούτων χαρακτῆρες ἅπαντες μέν εἰσι διὰ τῶν γραμμάτων, ἃ σημαίνει τὰ <πρῶτα> στοιχεῖα τῶν φωνῶν, πλὴν τοῦ κάτωθεν ἀπεστιγμένου δέλτα. τίνα δὲ διάνοιαν ἕκαστος αὐτῶν ἔχει, δηλώσω. μεμνημένων οὖν ἡμῶν, ὅτι τὰ πρὸ τοῦ τελευταίου τῶν χαρακτήρων, ὑφ' οὗ θάνατον ἢ ὑγείαν ἔφαμεν δηλοῦσθαι, γεγραμμένα τὸν ἀριθμὸν τῶν ἡμερῶν σημαίνει, περὶ τῶν ἄλλων, ὅσα μεταξὺ τούτων τε καὶ τῆς ἀρχῆς γέγραπται, ποιήσομαι τὸν λόγον. τὸ μὲν α δοκεῖ δηλοῦν ἀποφθορὰν <ἢ> ἀπώλειαν, τὸ δὲ γ γόνον ἢ γονοειδὲς οὖρον, τὸ δ' ἀπεστιγμένον δέλτα (καλοῦσι δ' ἀπεστιγμένον, ὅταν ὀρθὴν γραμμήν, οἵαπέρ ἐστιν Ι, κάτωθεν ἔχῃ, τρόπῳ τοιῷδε γεγραμμένον Δ) [ἱδρῶτα] ἢ διάρροιαν ἢ διαχώρησιν ἢ συνελόντι φάναι κένωσιν ἠντινοῦν σημαίνειν βούλονται, τὸ δὲ ε ἐποχὴν ἢ ἕδραν, τὸ δὲ ζ ζῆτημα, τὸ δὲ θ θάνατον, ὡς προείρηται, τὸ δὲ ι ἱδρῶτα, τὸ δὲ κ κρίσιν ἢ κοιλιακὴν διάθεσιν, τὸ δὲ μ μανίαν ἢ μήτραν, τὸ δὲ ν νεότητα καὶ νέκρωσιν, τὸ δὲ ξ ξανθὴν χολὴν καὶ ξένον τι καὶ σπάνιον καὶ ξυσμὸν καὶ ξηρότητα, τὸ δὲ ο ὀδύνας ἢ οὖρον, (ἔνιοι δέ φασιν, ὅταν ἐπικείμενον ἄνωθεν ἔχῃ τὸ υ, τότε σημαίνειν τὸ οὖρον αὐτό, γραφόμενον ὡς εἰώθασι τὸ οὕτως γράφειν,) τὸ δὲ π πλῆθος ἢ πτύελον ἢ πῦρ ἢ πυρετὸν ἢ πνεύμονος πάθος, τὸ δὲ πεῖ ἐν ἑαυτῷ μέσον ἔχον τὸ ι, καθότι προείρηται, τὸ πιθανὸν δηλοῖ, τὸ δὲ ῥῶ ῥύσιν ἢ ῥῖγος, τὸ δὲ σῖγμα σπασμὸν ἢ στομάχου πάθος ἢ στόματος κάκωσιν, τὸ δὲ τ τόκον, τὸ δὲ υ ὑγείαν ἢ ὑποχόνδριον, τὸ δὲ φ φρενῖτιν ἢ φθίσιν, τὸ δὲ χ χολὴν ἢ χολῶδες, τὸ δὲ ψ ψῦξιν, τὸ δὲ ω ὠμότητα.

reasonable that she died on the eighth day, the excretions having been retained".[120] Zeno likely argued that the symbols helped Hippocrates remember the particulars of the cases without lengthy explanations: the *Epidemics* were valuable because of the specificity of their empirical information and yet simultaneously difficult to set to memory on that account.

Zeno's claims were opposed by several Empiricists rather quickly. The sequence of Empiricist authors – Apollonius the Empiricist, Apollonius Byblas, Zeuxis – wrote in the early to mid second century BCE, very close to Zeno's defense of the markings' authenticity. Zeuxis' summary of the controversy was in fact so authoritative that it remained the standard reference for Galen, over three hundered years later. Galen records the progression of the controversy in his discussion of *Epidemics* III.8.

> For after Zeno wrote no small book about the marks, as I said earlier, next Apollonius the Empiricist wrote in opposition a second book greater than his, then later again Zeno wrote against him, so Apollonius surnamed Byblas wrote after these things and he not only refuted Zeno's book about the marks (Zeno was already dead) that they were revised but even made a so-called super-refutation [*παρεξέλγχον*] about them against Zeno. For since he [Zeno] was not able to interpret well what had been revised by Mnemon but among them was at a loss for reasonable arguments and changed the marks for the benefit of interpretation, Apollonius made his counter-argument, claiming that no copy[121] found in the royal library or in the storehouse of books from the ships or in the edition made by Bacchius had the marks, as Zeno wrote in the case of the present youth according to the report.[122]

The two Apollonii, both Empiricists, wrote books against Zeno. Whatever criticism Apollonius the Empiricist (*fl.* 175 BCE) wrote against Zeno (perhaps simply a long argument that the markings were inauthentic), Apollonius Byblas' (*fl.* 150 BCE) book eclipsed Apollonius the Empiricist's book in importance as a refutation of Zeno. Apollonius Byblas' case against Zeno depended on two points: that the markings did not appear in other editions of *Epidemics* III and that Zeno had changed the markings from

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[120] Galen *In Hipp. Lib. Epi. III Comm. II* 17A602K = 77.1-2 Wenkebach = Zeno fr. 5 vS.

[121] Reading <*οὐδὲν ἀντίγραφον*> with von Staden (2006: 21n.25) in preference to Wenkebach's <*οὐδὲν βιβλίον*>.

[122] Galen *In Hipp. Lib. Epi. III Comm. II* 17A.618-619K = 86.16-87.16 Wenkebach = Zeno fr. 6 vS = Empiricist fr. 342 D.

what did appear in Mnemon's copy. Apollonius Byblas scoured three different places for manuscripts to compare Zeno's text of the markings in *Epidemics* III with those elsewhere: he consulted manuscripts in the library at Alexandria and the storehouses which held material taken from landing ships, just as in Galen's retelling of Zeuxis' story above.[123] He also consulted Bacchius the Herophilean's edition (ἔκδοσις) of *Epidemics* III, although what exactly ἔκδοσις might mean is in some doubt.[124] Apollonius Byblas enlisted the respected writings of Bacchius, a fellow Herophilean of Zeno, against Zeno. Apollonius Byblas found the markings in none of these texts in Alexandria and for this reason denied that the markings were authentic to the Hippocratic text.

Apollonius Byblas' second argument against Zeno was that Zeno had changed the markings from Mnemon's original book. Presumably then Mnemon's book or an account of Mnemon's markings was available to Apollonius Byblas (was it in Zeuxis' history of the markings?) to check against Zeno's presentation. In fact it does appear that there were *variae lectiones* of the markings after the case history of *Epidemics* III.7. The modern text of *Epidemics* III.7 reads

> ἡ κυναγχικὴ, ἡ παρὰ τὰ Ἀριστιῶνος, ἣ πρῶτον ἀπὸ γλώσσης ἤρξατο· ἀσαφὴς φωνή· γλῶσσα ἐρυθρή· ἐπεξηράνθη. τῇ πρώτῃ, φρικώδης· ἐπεθερμάνθη. τρίτῃ, ῥῖγος· πυρετὸς ὀξύς· οἴδημα ὑπέρυθρον, σκληρὸν τραχήλου καὶ στήθεος ἐξ ἀμφοτέρων· ἄκρεα ψυχρὰ, πελιδνά· πνεῦμα μετέωρον· ποτὸν διὰ ῥινῶν ἐχεῖτο· καταπίνειν οὐκ ἠδύνατο· διαχωρήματα καὶ οὖρα ἐπέστη. τετάρτῃ, πάντα παρωξύνθη. πέμπτῃ, ἀπέθανε, κυναγχική.
>
> Throat cold at the house of Ariston [*al.* Biton], which began from the tongue: the voice was unclear, the tongue red, he dried out. On the first day shivering, he got warm. On the third day cold, a sharp fever, a slightly red swelling, hardness of the throat and both sides of the chest, cold and pale digits. Air elevated. He retained drink in his nose, he couldn't drink. Excretions and urine blocked. On the fourth day everything peaked. On the fifth day he died, a throat cold.

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[123] From this piece of evidence it would seem that Apollonius Byblas lived in Alexandria and had access to all these books at the library and elsewhere. Nonetheless, Ps.-Galen εἰσαγωγὴ ἢ ἰατρός 14.683K = Empiricist fr. 6 D explicitly names both Apollonii as Antiocheans, Apollonius the Empiricist and Apollonius Byblas; he also says they were father and son. I do not want to suggest that the Rationalist/Empiricist dispute can be read as an Alexandria/Antioch proxy agon of the Ptolemaic and Seleucid kingdoms. Rather it seems that many Empiricists came from Alexandria or visited there and some Rationalists lived in Antioch, such as Apollophanes of Selecuia, Erasistratean and court physician to Antiochus III the Great (see Keyser and Irby-Massie (2008: 117-18)), or visited Antioch, if the stories about Erasistratus' stay at the Seleucid court are true.

[124] See von Staden (2006: 22-25).

Galen records that the text of *Epidemics* III.7 was in some doubt, with some people saying that the patient died on the fifth day, others on the seventh day, and still others on the eighth. Artemidorus Capito, a Hippocratic editor the generation before Galen, removed mention of the days altogether, while Galen himself read that the patient died on the fifth day.[125]

> I am indeed amazed, as I said, that although the more exact copies have the fifth day and although the copy and the letter itself agrees with the writing, as I showed a little before, Zeno himself understands the eighth day to have been written and those opposing him have said nothing about this and that [they opposing him] about the markings refute him on the grounds that he altered the second letter, making it a marked-off delta, although this writing is not the case in the third book of the *Epidemics*, but that after the first marking a P was written, just as they say.[126]

"Those opposing Zeno" is probably a reference to Zeno's Empiricist critics, at the very least Empiricists who had Mnemon's book or a record of its readings; whether they were the Apollonii is unproven but plausible. Zeno's Empiricist critics claimed that Mnemon's markings were not ΠΔΕΗΘ (as Zeno claimed) but ΠΡΕΗΘ. Thus Zeno had altered Mnemon's writing so that the sequence ΠΔΕΗΘ made medical sense. (Galen himself found a still different class of markings, as he indicated in reference to the days: ΠΡΕΕΘ.) It is not clear what Mnemon's sequence ΠΡΕΗΘ ought to mean in reference to the case history of *Epidemics* III.7. The letter *rho* in Zeno's explanatory system ought to stand for either a disease, a quality, or a body part relevant to the case: ῥίς "nose", ῥῖγος "cold", and ῥύσις "flow" are possible candidates but none are relevant to the case at hand, a man who died of a swollen throat. (Galen in fact spends some time dismissing the medical possibility that he died of a cold or from problem with his nose: his point is that Hippocrates states twice that the problem was the throat cold, *κυναγχική*.)

Both of Apollonius Byblas' arguments against Zeno's interventions depend on a

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[125] Galen justifies his reading on both philological and medical grounds *In Hipp. Lib. Epi. III Comm. II* 17A.594-600 = 72.1-75.22 Wenkebach.

[126] Galen *In Hipp. Lib. Epid. III Comm. II* 17A.602-603 = 77.3-24 Wenkebach = Empiricist fr. 341 D = Zeno fr. 5 vS.

strong sense of textual conservatism. If the markings are authentic Zeno ought not to have altered the letter sequence; if they are authentic, the letters ought to be preserved in other copies of *Epidemics* III. But Zeno's case for the markings' authenticity fail both of these criteria: the letters were in no other copies of the *Epidemics* III nor did Zeno preserve the letter forms which Mnemon's book had. At stake for Apollonius Byblas is the accuracy of copies of Hippocrates' ἱστορία. (Galen's argument is quite different; he argues primarily for the markings' inauthenticity on medical grounds.)

Empiricist textual conservatism in Hippocratic exegesis is the *consequence* of Hippocrates' empiricism. The authenticity of Hippocrates' ἱστορία matters: Hippocrates' reports of his ἐμπειρία is worthy of study and emulation by Empiricist physicians and, insofar as Hippocrates' ἐμπειρία is worthy of study, he has already been co-opted as an Empiricist physician. Empiricist commentators are not searching for Hippocrates' empiricism; they are studying it. Recall that ἱστορία refers both to the transmitted report of earlier physicians and the present doctor's investigation into these reports as an attempt to supplement his own experience. In Hippocratic exegesis then Empiricists have changed the emphasis and understanding of the second leg of the Empiricist tripod, the ἱστορία: the Empiricists have ranged from the *investigation* of Hippocrates' empiricism to the bare *report* of it. Both senses of ἱστορία are present in the Empiricists' understanding of Hippocrates.[127] In the controversy about the markings, then, the investigation of the reasons why patients lived or died – a medical argument – becomes replaced by the report of why the text says they did so, a philological argument.

The rereading of the debate between Rationalists and Empiricists has brought to the fore a number of the strategies used by each sect in their asymmetrical debate. The Rationalists continued to view the debate in terms of causality and knowledge. Ps.-Dioscorides argued that there was need to know the properties of *pharmaka* as a class to understand better the causal chain of the body. Hegetor argued that knowledge of the internal anatomy of the body was needed to understand the causes of injury and disease. Zeno, the Rationalist commentator of Hippocrates' markings, emended the markings to

[127] LSJ *s.v.* I.1 and II.

give them medical sense. The Empiricists, by contrast, adopted a strategy of cultural traditionalism against the Rationalists about the doctor's role in medicine in addition to their epistemological critique of the Rationalists. Apollonius of Citium argued that his ἐμπειρία and the ἱστορία of Hippocrates show that Hegetor's logic is false: a dislocated hip bone can be reset. The Empiricist authors who interpreted Hippocrates aimed to preserve the ἱστορία of Hippocrates through textual conservatism and thereby understand Hippocrates' empiricism.

Chapter 5: Conclusions

This chapter levels possible presentist criticisms against the methodology of this study. It considers which categories from sociological studies of modern science are applicable to ancient science. It summarizes the results of the entire study and suggests avenues for future research.

5.1 Presentism in the Historiography of Science

The present enters the past in many ways. Historians must be on their guard against writing a history of the present using materials of the past.[1] In the history of science two of the most common forms of presentism, the act of imputing contemporary objects, categories, and ideas to a historical moment where they did not exist, are Whiggism and the confusion between actors' and observers' terms. I take Whiggism in a broad sense in the historiography of science: any historiographic principle by which historians give or explain chronological sequence to undated historical material according to its 'scientific progress' or, conversely, explain a known dated sequence on the assumption that 'scientific progress' is occurring. In the historiography of science confusion between actors' and observers' terms includes issues not only about the term 'science' but also about modern ways of viewing nature.

To explain the terms of Whiggism I begin with a comparative example from modern history of science studies where the relative dates of the evidence are known. Lorraine Daston and Peter Galison's (2007) *Objectivity,* one of the most feted history of science studies of the last decade, traces the historically contingent development of scientific objectivity.[2] Their opening pages describe a 19th century British physicist

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[1] I once heard this quote attributed to Michel Foucault but cannot find the reference. Is it merely an academic boogeyman, the warning of each generation of faculty advisors to their students?

[2] But see Forman (2010: 172 n.36) for a critical notice: "The fate of objectivity in postmodernity is inseparable from the distain of disinterestedness. Of this one finds no recognition in Lorraine Daston, Peter Galison, *Objectivity*, Brooklyn, N.Y.: Zone Books 2007, but, instead, a panglossian multiplication and accumulation over time of "epistemic virtues" in parallel with "political virtues such as freedom and solidarity" (p. 363, 367). If, however, objectivity is the constant companion of solidarity, then the continuing collapse in contemporary societies of every form of social solidarity argues, rather, that the fate

peering into a microscope to study the appearance of individual milk drops impacting a glass plate.

> He lit his laboratory with a powerful millisecond flash—poring over every stage of the impact of a liquid drop, using the latent image pressed into his retina to create a freeze-frame "historical" sequence of images a few thousandths of a second apart. Bit by bit, beginning in 1875, the British physicist Arthur Worthington succeeded in juxtaposing key moments, untangling the complex process of fluid flow into a systematic, visual classification … For Worthington himself, the subject had always been, as he endlessly repeated, a physical system marked by the beauty of its perfect symmetry … For years Worthington had relied on the images left on his retina by the flash. Then, in spring 1894, he finally succeeded in stopping the droplet's splash with a photograph. Symmetry shattered. Worthington said, "The first comment that any one would make is that the photographs, while they bear out the drawings in many details, show greater irregularity than the drawings would have led one to expect." But if the symmetrical drawings and the irregular shadow photographs clashed, one had to go … For two decades, Worthington had seen the symmetrical, perfected forms of nature as an essential feature of his morphology of drops. All those asymmetrical images [he had drawn] had stayed in the laboratory—not one appeared in his many scientific publications. In this choice he was anything but alone—over the long course of making systematic study of myriad scientific domains, the choice of the perfect over the imperfect had become profoundly entrenched. From anatomical structures to zoophysiological crystals, idealization had long been the governing order. Why would anyone choose as the bottom-line image of the human thorax one including a broken left rib? Who could want the image of record of a rhomboid crystal to contain a chip? What long future of science would ever need a "malformed" snowflake that violated its six-fold symmetry, a microscopic image with an optical artifact of the lens, or a clover with an insect-torn leaf? But after his 1894 shock, Worthington instead began to ask himself—and again he was not alone—how he and others for so long could have only had eyes for a perfection that wasn't there.[3]

After nineteen years of study by eye alone Worthington moved from seeing a uniform appearance of the impacted milk drops to in 1894 seeing at once by photography an irregular and changing impacted milk drop. Worthington valued systematic symmetry over other depictions until confronted with photographic evidence; he published only drawings of symmetrical splashes and kept the asymmetrical drawings in his laboratory.

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of the "epistemic virtues" cannot be rosy – not to mention what passes for objectivity in societies still today premodern, and on that dreadful basis still semi-solidary."

[3] Daston and Galison (2007: 11-15).

So when was Worthington doing science in 1893: in the morning when he looked into his microscope and drew an asymmetrical splash? in the afternoon when he drew a symmetrical splash? Or was he doing science when he published the symmetrical drawings and propagated an image of natural regularity? Was he doing science in 1895 when he trusted machines instead of his eyes? In short, does doing science mean only that progress in some form is occurring?

Daston and Galison are able to problematize immediately the historical development of the judgment of one modern scientist because they have dated evidence from notebooks and from publication papers. Imagine now the historiographical conundrum if they lacked dated evidence for which came first, the regular impacts or the irregular impacts. Would Worthington have published the asymmetrical drawings, keeping the symmetrical drawings in the laboratory, and thereby have propagated an image of natural irregularity and complexity? Would he have then claimed in 1894 that technology vindicated his eyes? In my alternate history the story of Worthington's impacted milk drops is a story of increasing improvement in scientific seeing and a lack of order and regularity in nature: in this alternate history, science is progress in technology. Worthington himself thought that the milk drops showed regularity in nature and he expected technology to vindicate the symmetrical patterns he saw by eye; the story of the milk drops was both the increasing revelation of order in nature *and* the improvement of seeing technology: for Worthington before 1894, science was progress in the revelation of regular natural order. Yet Daston and Galison's story is complete only when the known historical development in seeing technology interrupts expected patterns of order and regularity in nature: for Daston and Galison, science is objective progress in seeing.

How might the theories of historians of modern science impact the interpretation of ancient science? The counterfactual about the loss of datable evidence is a very real problem in the historiography of ancient science. Chapters 2 and 3 showed that both Herophilus and Archimedes addressed a certain technical problem multiple times in multiple ways. In the absence of dated evidence past scholarship has tried to date the different attempts by assuming that Herophilus' and Archimedes' handling of the

technical material improved: these scholars tell a story of improved 'ways of seeing.' And thus their interpretation of the ancient material implicitly incorporates a historiography of theoretical progress. But the story of Worthington's milk drops shows that assumed progress as a historiographic principle can take multiple forms and implicitly incorporates a definition of science as progress into history.

The thrust of this study has attempted to address the historiographical problem of the sequence of multiple solutions by the same scientific author from the standpoint of literary theory, namely how texts relate to other texts. Chapter 1.3.1 inscribed the literary relationship between texts in anthropologic terms: the actors' category intertextuality$_A$ marks the ancient scientific author's ability to allude to predecessor texts; the observers' category intertextuality$_R$ marks the ability of the reader figured as the modern historian to collate and compare predecessor texts. By using intertextuality$_R$ as an interpretative principle chapter 2.2 held in abeyance the question of chronological priority of the fragments of Herophilus' pulse theory while emphasizing both the continuity and difference of Herophilus' work. By using intertextuality$_A$ as an interpretative principle chapter 3.2 showed how Archimedes controlled the reader's ability to read predecessor texts into the mechanical way of seeing of the *Ephodos*. Herophilus' multiple attempts to time the pulse attributed more empirical phenomena to the pulse as a materio-semiotic object: this is a story of an increasing revelation of order in nature. Archimedes' mutiple attempts to measure the parabola's area contributed to the particular kind of the *Ephodos'* mechanical 'way of seeing': this is a story of improved seeing technology. 'Scientific progress' results from the emergence of new objects and approaches in science; and the scientific progress told in chapters 2 and 3 comes from Herophilus and Archimedes, not the modern historian.

Daston and Galison's book raises concerns not only about implicit teleology but category differences in different historical epochs: it raises a number of questions about nature and ways of seeing nature. The book can be viewed as an extended argument that the mental categories with which modern scientists operate are historically contingent, imprinted from a certain cultural moment: for example, at some point objectivity became

a scientific virtue and came into its present shape of being.[4] To speak dialectically, modern scholars are accustomed to think of 'nature' as something immutable, a given, and to think of 'culture' as a changeable object. Yet this categorical divide itself can be shown to be the product of a specific cultural moment, at least in modern European thought around the turn of the 18th to 19th centuries.[5] The concept of 'nature', what is given, has a history, just as much as 'ways of seeing nature' (of which objectivity is a part) have a history.

Can we therefore speak about 'science' in Greco-Roman antiquity? If 'nature' and 'ways of seeing nature' have histories, it is not clear that scholarship can claim to speak about 'science' and its object, 'nature', in Greco-Roman antiquity: doing so imputes modern categories and values to ancient conceptions of nature and natural investigations. To speak of 'science' in antiquity is presentism in the form of confusion between actors' and observers' categories. Roger French's (1994) general introduction to the Routledge series 'Sciences in Antiquity' (printed only in the volumes *Ancient Astrology*, *Ancient Natural History*, and *Cosmology in Antiquity*) strongly denies that one can speak of 'science' at all in Greco-Roman antiquity, only natural philosophy.

> First, as a practical matter, in a wide survey such as this it is clearly undesirable to proceed by means of modern categories … It is more appropriate to use subject areas that were recognised in antiquity, in order that some account can be given of them that reflects both ancient—rather than modern—categorisation and their cultural context … Medicine, for example, (to mention briefly the subjects covered by the series) was a vocational rather than liberal discipline, as clearly defined in the ancient world as now, for there have always been people who have tried to cure disease and maintain health. Mathematics also in a sense defines its own subject areas (arithmetic and geometry) in a way that largely coincides in the modern and ancient periods (and which also partly coincided with the quadrivium). Natural history too is a category recognisable equally to Romans, at

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[4] My best attempt at neutral language in this context is 'historically contingent' instead of 'historically' or 'socially' constructed. As will be clear below in 5.2, the phrase 'historically contingent' does have social constructivist overtones, which is the interpretative tradition to which Daston and Galison (2007) weakly belong. Nonetheless, at the present I intend no more than the uncontroversial genealogical claim that scientific ideas come into the mind of scientists at certain historical points.

[5] Beyond the bibliography in Daston and Galison (2007), see also Flemming (2000: 5.n9) with reference to Daston (1998). As a classicist one thinks more readily of the *nomos*/*physis* dialectic of Greek intellectuals in the 5th century BCE. The historiographical division between an established, given nature and mutable culture exists in both ancient and modern thought.

> least, as to moderns. Astronomy without its constant companion astrology is perhaps a modern category rather than ancient and its *separate* history is partly a construction of scientific historians. Astrology is as recognisable as medicine, with a body of practitioners, clients and a technical subject matter, practised in a society of which the economic, intellectual, religious and political aspects all had a historical role to play …
>
> A brief, ordinary characterisation of science would surely include most of the following: (i) It is objective … (ii) It is non-religious…(iii) It is experimental in its verification of its theories, (iv) Science and the research that continues to build it are in practice directed to the practical business of manipulating nature … (v) Its manipulative nature has strong links to technology, (vi) It has universal law-like statements, often mathematical and with Boyle's law as a paradigm. Little of this can be found in the ancient world …
>
> Some historians have recently recognised that to see science in antiquity we have to have a definition of science so broad as to be meaningless. Whether it is Aristotle's 'all men by nature desire to know' (he said it in the *Metaphysics* and by any account it is a broad definition) or a 'systematic knowledge of nature' we are left with something so vague that it can scarcely have a history. Why, after all, should we use a modern term to denote ancient usage, when the categories and terms of the past are better? … It was argued above that the subject areas of this series were recognisable in the ancient world, which means that each was practised by more than a single man. The doctors could see medicine as a discipline that would grow on the basis of accumulated experience, and so to an extent were consciously laying the foundations for the development of an autonomous discipline. Aristotle too recognised that natural philosophy was an exercise that might by further observations in the future resolve problems obscure to him. But they were not laying the foundations of our disciplines. Just as both Aristotle and the doctors constructed histories to legitimate their own activity and to mark it off from others, so by the same token when they looked to the future they saw an extended Aristotelian natural philosophy and a future (let us say) Asclepiad medicine. Nothing else would count as the real thing … Using 'science' in the past *creates* problems because it looks different from philosophy; in doing so it also—because of a perceived opposition between science and religion—obscures the relationship between philosophy and religion.[6]

French's account is an energetic argument against calling anything in Greco-Roman antiquity 'science'. According to French, we can recognize that the subject matter of ancient domains were similar to the subject matter of contemporary science. Yet the essential features of modern science – objectivity, universality, technology – did not exist in antiquity. Alternate modern definitions are no good because they are too broad. Our

[6] Cited from Tamsyn (1994a: xii-xxi). Emphasis in the original.

terms of historical description should be those of the historical actors themselves. These historical descriptions are practices of natural philosophy, not our sciences. Thus, it is principally from philosophy that practices of ancient natural philosophy develop and are defined.

French's polemic is best summarized in the question: why use a modern term when the terms and categories of the past are better descriptors of the past? At issue is how observers construct historical actors' terms and understand their categories. French would certainly be opposed to the starting points of the present study. In chapter 1.1 I drew the picture of 'science' in the Hellenistic period without reference to philosophy; I defined 'science' in sociological terms and endorsed the application of sociological studies of modern science to 'science' of the Hellenistic period. Perhaps it may be charged that my methodological choices and the label itself of 'science' are presentisms, modern categories and concepts smuggled across the historical divide into the readings of ancient texts.

5.2 THICK AND THIN SOCIAL DESCRIPTIONS

I plead guilty to the charge of presentism in discriminating 'science' strictly from 'philosophy'. This has been a deliberate methodological choice. I believe, with French, that philosophy played an integral part in Greco-Roman conceptions of nature and that it is impossible to draw a complete picture of science in the Hellenistic period without reference to philosophy.[7] But the point of investigating Hellenistic 'science' without reference to philosophy was to learn what 'science' contributes to *our* picture of *their* investigations concerning the natural world. That is, the present study aimed to gain a deliberately one-sided view of what Hellenistic practitioners of 'science' thought that they were doing in that activity. The purpose of the presentist discrimination of philosophy was to specify more precisely the historically contingent category which we are studying.

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[7] For example, Nussbaum (1994) shows the explicit importance of the cultural role of the doctor in Hellenistic philosophical schools, even as it presents a one-sided view of the relationship between philosophy and science (she does not engage at all with the Hellenistic medicine schools).

So French's point that ancient 'science' does not wholly map onto the contemporary category remains. It is easy to show that French's description of the essential characteristics of contemporary science and his corresponding claim that science in Greco-Roman antiquity lacks these features are simplistic and tendentious at best, outright false and a distortion at worst.[8] Ancient science does take an interest in all six of French's essentialist characterizations, even if not everyone would agree that these features are essential to 'science'. In fact, modern science is no more essentialist than ancient science: even intelligent sociological models of science from the 1960s and 1970s rarely approximate the contemporary reshuffling of science departments and disciplines into research unit groups.[9]

Better then to take French's argument as the representative of a certain kind of argument, the essentialist great divide between Ancient and Modern. To argue against this divide, we might evaluate the elements of Greco-Roman science we have seen in this study by the essentialist classification of modern science; let us therefore call the principles of our science realist and the principles of their science relativist. We could call relativist Herophilus' names of the pulse, the Empiricist transition to the similar, or Archimedes' mechanical method; we could call realist (and thus appropriate as part ouf our science) Herophilus' distinction between arterial pulsation and muscle spasms or the Euclidean style of geometric argumentation. And yet neither of these broad labels tells us observers much about what the Greek authors thought that they were doing with their investigations. When we posit a great divide between *us* and *them* we fixate only on the gap. We schematize, we draw generalizations, we worry, as Netz (2004b) has said, about the route from A to B at the expense of good analysis of A or B *per se*.[10] A focus on the relativism or realism of Hellenistic investigations into nature, or 'science', is an extended application of applying our own categories, an exercise that tells more about *our* perspective and how *we* got here than historical actors' perspective on investigations into nature.

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[8] See the review of Lennox (1998: 471-72).
[9] Biagioli (2009: 819).
[10] Netz (2004b: 7).

Consider also the philological claim from chapter 1.1 that the Greeks have no word for science. The English word 'science' has a long history associated first with elements of theological study in the medieval quadrivium and at last exclusively with natural and physical sciences in the mid-nineteenth century.[11] The term 'scientist', on the other hand, is only attested in English from 1834.[12] It would be ludicrous to use this philological evidence to suppose that people did not do science in our contemporary sense before the nineteenth century. Rather, the best conclusion we might draw is that people (at least in English) did not, or rather, could not *describe* themselves as 'scientists' before the nineteenth century.[13] Philological evidence does not stretch very far as evidence for social practices; it is only a thin description.[14]

I have titled this section "Thick and Thin Social Descriptions" in homage of Geertz (1973) because his famous dicta vivify the interpretative principles of my study.

> The concept of culture I espouse, and whose utility the essays below attempt to demonstrate, is essentially a semiotic one. Believing, with Max Weber, that man is an animal suspended in webs of significance he himself has spun, I take culture to be those webs, and the analysis of it to be therefore not an experimental science in search of a law but an interpretative one in search of meaning. It is explication I am after, construing social expressions on their surface enigmatical.[15]

The prescriptive account of an essentialist study of science is a thin description of the actions of scientists and the society in which they live: a set of formal characteristics regardless of place, time, or people. What can a thin description of scientific knowledge tell but that Greek science is not our science? A thick description of science, on the other

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[11] *OED s.v.* 1a, 3a, 5a, 5b.
[12] *OED s.v.* 1.
[13] The clearest work on historical identities in the discipline of Classics come from gender studies. Work on historical identities in modern societies have also considered descriptive psychology. I have modeled this paragraph on Hacking's (2002) account of psychological deviance in the nineteenth century.
[14] Lesley Dean-Jones reminds me that ancient Greek has no word for 'family' to designate the nuclear family: they have words for mother, father, son, and daughter. Yet clearly Greeks recognized a nuclear family within the household: the absence of a word for 'nuclear family' does not indicate that these members of the nuclear family did not perceive themselves as a distinct unit within the *oikos*. Analogously, the absence of an ancient Greek a word for 'science' does not indicate that they failed to recognize some investigation of *physis* crossing the domains of medicine, mathematics, music, mechanics, and so on.
[15] Geertz (1973: 5). Geertz himself credits Gilbert Ryle for the phrases "thin description" and "thick description."

hand, is contextual and interpretative: knowledge production described in both actors' and observers' terms with an awareness of "the knowing traffic between ancient and modern categories of analysis."[16] And so the invocation of sociological models of 'science' to ancient Greek mathematics and medicine is imputing to Greek mathematicians and Greek doctors the ability to be the object of sociological study, that is, the ability to represent – ideographically, metaphorically, socially – their interpretation of the natural world. The human as a representing animal, I am convinced, is no presentism.

The tenor of this study has been to reject essentialist characterizations of science from the start.[17] It is clear that French's account is on the whole a bad argument that leads to a fairly misguided debate about labels. Comparing essentialist characterizations of Greek science to essentialist characterizations of modern Western science generates more heat than light.[18] Here then is an appropriate time to step back from the particulars

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[16] Whitmarsh's (2001: 4) wonderful tag for scholarship in the field of Classics.

[17] In older philosophy of science literature, essentialist characterizations are called by the technical term 'demarcation criterion', which originates with the work of Karl Popper.

[18] The introduction of Keyser and Irby-Massie's *Encyclopedia of Ancient Natural Scientists* (2008: 1) is also an essentialist argument: "It is proper to describe the work of the people included herein as "science," with no more risk of anachronism than using any modern term to refer to a corresponding ancient practice, because the ancient models of nature, whether correct or not, were indeed attempts at *models*. That is, they were created and debated as abstracted descriptions of phenomena, intended to give a naturalistic and self-consistent causal account, of a world viewed as regular or constant in its behavior. Their methods and aims were scientific, even when their theoretical or intellectual achievements are ones we now perceive as inaedequate. Histories of science must be comprehensive, including all abandoned paths, since roads *not* taken seem inevitable only in hindsight." Emphasis in the original. They, unlike French, are concerned to close the gap between Ancient and Modern: essentialist features allow *our* recognition of *their* science even when results differ. It is hard to determine what Keyser and Irby-Massie mean by "modeling", their essentialist feature of science. On the one hand, modeling may mean no more than descriptions of natural phenomena including causal features; on the other hand, modeling may imply that the description is representation only, not an objective account. I argue that both of these senses of modeling as essentialist features ultimately fail to capture Greco-Roman science. First, not all scientists in Greco-Roman antiquity were interested in causal explanation or in creating a theoretical account of natural phenomena, as chapter 4 on the Empiricists showed. Second, the canonical example from the history of science of a model of natural phenomena without commitment to its objective reality is Andreas Osiander's introduction to Copernicus' *De Revolutionibus*. Gingerich (2004) is an interesting qualification of the thesis that *De Revolutionibus* was widely understood merely as a modeling attempt. Even without reference to Copernicus, however, Keyser and Irby-Massie would need a sustained discussion of evidence of scientists' beliefs that they intended no commitment of their models to objective reality. I do not believe that there is evidence for that thesis nor that the thesis would be useful as a motive to explain how Greco-Roman scientists act. Once again, essentialist arguments generate more heat than light.

of French's argument and consider the applicability of non-essential descriptions of science to the ancient material.

I disagreed with French how observers construct historical actors' terms and categories. Since in this study I conceived of myself as an anthropologist studying Hellenistic period scientists, I had some observer's categories with which I interpreted the scientific practices of historical actors: I applied comparative ethnographic categories drawn from sociological studies of modern science to the scientific practices of historical actors. Therefore, I now consider sociological characteristics of modern science and evaluate the ancient material in these categories.

This study has cited modern sociology of science literature, much of which is social constructivist in nature.[19] The philosopher Ian Hacking's (1999) *The Social Construction of What?* has developed a useful typology of literature about social construction in many fields, including natural science.[20] The American 'Science Wars' of the 1990s, crystallized by the hoax of physicist Alan Sokal,[21] distinguished between scientific realists (Sokal and his allies) and social constructivists (Sokal's targets). Hacking argues that the social constructivists are distinguished by their commitments to the contingency of science and explanations of stability external to science.[22] Applying Hacking's typology about the contingency of science and explanations of stability external to science to consider the possibility of a social constructivist description of ancient science, I argue that ancient science was contingent but not stable in the same way as modern science.

The contingency of science is the thesis that the present state of science was not inevitable. Contingency takes many forms: historical, metaphysical, etc. Historical contingency is the category which concerns historical treatment. Hacking ties

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[19] Latour would not claim that label for ANT because he denies that 'the social' is an explanatory category; see Latour (2005).

[20] See especially Hacking (1999: 63-99), who classifies himself as a moderate constructivist. For more up-to-date bibliographies of social construction see (from Anglo-American philosophy perspectives) Longino (2006), Mallon (2008), and also Daston's (2009: 803-4) bibliography of the 1990s 'Science Wars'.

[21] See Hacking (1999: 3) for an account.

[22] Hacking (1999) also argues that the participants in the debate further disagree on the role of nominalism in science. Hacking's thesis is that, philosophically analyzed, the debate between scientific realists and social constructivists is another instantiation of the debate between positivists and nominalists.

contingency to the notion of progress and development in science: a constructivist argument claims that the present scientific order, whatever it is, could have been different and still be considered a scientific account of the natural world. French's account of ancient science cited above employs an argument about the progress of ancient science from the point of view of the ancient practitioners: "Just as both Aristotle and the doctors constructed histories to legitimate their own activity and to mark it off from others, so by the same token when they looked to the future they saw an extended Aristotelian natural philosophy and a future (let us say) Asclepiad medicine. Nothing else would count as the real thing."[23] Science took a path different from that its ancient practitioners expected; and since French aims to emphasize the gap between *their* science and *ours*, this indicates the falsity of *their* science. The implication of French's argument is that, by contrast to the ancient, *our* science is not contingent: our scientific ideas and theorems, correct and valid, could not have been otherwise.[24]

But modern science is just as historically contingent as ancient science. Now it is often the aim of genealogical scholarship to describe the historical (and thereby social) contingency of cultural artifacts, codes, and descriptions with the implication that, by being historically and socially contingent, they are less real, less logically compulsive, less objectively so.[25] Nevertheless Lorraine Daston, from her perspective as a historian of science, has articulated a different view:

> Probably most historians of science these days, if asked about an episode like the refinement of precision measurement techniques or the formulation of statistical correlation, would answer that such scientific practices are both socially constructed *and* real. That is, they depend crucially on the cultural resources at hand in a given context (mid-nineteenth-century industrializing Prussia, early twentieth-century eugenics-obsessed Britain) *and* they capture some aspect of the world; they work. But they are neither historically inevitable nor metaphysically

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[23] Cited from Barton (1994a: xx). Keyser and Irby-Massie (2008:1)'s essentialist argument (see footnote 18) also allows for the contingency of ancient science: "Histories of science must be comprehensive, including all abandoned paths, since roads *not* taken seem inevitable only in hindsight." Emphasis in original.

[24] Here then French offers another essentialist characterization of modern science, again chosen to emphasize the divide between Ancient and Modern.

[25] Hacking (1999: 19) charts six increasing degrees of social constructionist attitudes: historical, ironic, reformist, unmasking, rebellious, revolutionary. My reading of Daston and Galison (2007) above in 5.1 is that they are 'historical' social constructionists.

> true. Rather, they are contingent to a certain time and place yet valid for certain purposes.[26]

Now from the realism/relativism dichotomy sketched above, many aspects of investigations of nature in Greco-Roman antiquity are not objectively real, i.e. valid within *our* scientific system, but Daston does not say that the results of modern science are objectively true, only that "they work" and "are valid for certain purposes." This is an explicit appeal to her readers' experience of the force of science in their lives. Such an appeal could be rewritten anthropologically to cover contemporaries' experience of a particular knowledge production within any given culture. Conceivably then we could appeal to the experience of our historical actors that, e.g. Greek mathematics, worked and satisfied in some deeply cultural way. This is to appeal to historical actors' belief, a category that most historians would deny is epistemologically knowable without explicit evidence. It is clearly beyond the scope of the present work to conclude that no such evidence exists;[27] but in the absence of present research on the topic, it is better for the historian to be skeptical about the phenomenological force of Greco-Roman science on historical actors' beliefs.

Greco-Roman science is historically contingent; its progress could have been different. In chapters 2 and 3 we have seen at least two paths not followed by the ancient practitioners of the same domain. Herophilus' use of the water-clock to measure pulse rates is the path not taken by ancient medical theory of the pulse.[28] As I argued in chapter 2, the ancient evidence shows that Herophilus employed a normative concept of time to measure pulses, expressed both through the application of the water-clock and by rhythms based on Aristoxenus' theory of the *protos chronos*. But Herophilus' normative

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[26] Daston (2009: 813). I offer Daston's example from the natural sciences instead of Hacking's (1999: 119) example of childhood autism from the human sciences; but they are both saying the same thing.

[27] Certainly a great deal of circumstantial evidence (as opposed to direct evidence) exists from honorific inscriptions, official appointments, and legal regulations for the cultural prestige of particular sciences (such as medicine and astrology) and for individual scientists like Archimedes and Galen.

[28] Lloyd (1987: 282-84) has argued that Herophilus' use of the water-clock was part of the ambition to represent medical inquiries mathematically, even if the attempt itself fell short of accuracy. Lloyd's chapter discussing Herophilus, "Measurement and Mystification", is itself arguing against Alexander Koyré's (1948) thesis that Greco-Roman science ought not to be called 'science' because of its lack of quantitative reasoning.

measurement techniques had mixed success in Greek medicine. None of Herophilus' sect followers seem to have employed his water-clock; and Galen eventually did away with Herophilus' application of the *protos chronos*, opting instead for a more descriptive analysis of pulse rhythm, as Appendix A shows. Despite Galen's radical reformulation of Herophilus' theory, Greek medicine could have been purely Herophilean in its analysis of the pulse; there was no metaphysical or historical necessity for the triumph of Galenism. The apparently complete failure of Herophilus' analysis by water-clock to establish and maintain its hold in Greek medicine might in fact be due to social limitations of the theory, such as the embeddedness of the Egyptian style of water-clock in its local environment.

Archimedes' application of mechanics to mathematics is an alternate path for mathematics in antiquity. There is some evidence that Archimedes' immediate Hellenistic successors employed similar analyses in their own mathematical work. Knorr (1986) argued that Dionysodorus' *On the Torus* was based on Archimedean principles of two-dimensional geometric shapes revolving around centers of weight, just as Archimedes does in the *Ephodos*.[29] Eratosthenes' *Letter to Ptolemy III Euergetes*, preserved by Eutocius, justifies its analysis of mean proportionals through an instrumental proof.[30] Regardless of whether an instrumental proof is the same as a mechanical proof in Greek mathematics,[31] Archimedes' mathematical work with mechanical principles seems to parallel a great deal of similar analyses in the late third and early second centuries BCE. At this point it must remain an open question for research whether Archimedes' mechanical treatises provided inspiration for the subsequent generation of Hellenistic mathematicians. Nonetheless, even if Archimedes' mechanical approach was applied successfully in the subsequent generation of

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[29] Knorr (1986: 263-70).

[30] I follow Knorr (1989: 77-153) and Netz (2004b: 294.n153) in holding that the entire letter is genuine. Geus (2002: 175-205), who follows Wilamowitz's (1894) argument that only the final dedicatory poem is genuine, seems not to know Knorr's (1989) contribution to the debate. Netz's (2004b: 297.n176) remark that "the author assumes we have seen the pillar" dissolves much of Wilamowitz's confusion about the multiple parts of the letter.

[31] See Sefrin-Weis (2010: 228-29) for a possible distinction between διὰ τῶν μηχανικῶν and διὰ τῶν ὀργανικῶν.

mathematicians, Greek mathematics remained Euclidean, as Pappus and Eutocius demonstrate.[32]

Hacking's other classification of social constructivist arguments is the explanation of stability external to science. Social constructivists argue that the causal means by which scientific debates come to an end, or have closure, are social factors (group coherence, financial hurdles, etc.). The social constructivist tradition, led sociology-inspired historians like Steven Shapin, has argued that modern science has social mechanisms to achieve closure. Shapin's (1994) famous thesis is that the values of honesty and mutual trust from social codes of 17th century gentlemen allowed the rise of scientific bodies, like the Royal Society, to arbitrate and judge disputes between scientific opponents.[33] By contrast, premodern science – that is, culturally specific knowledge production before the 16th century – had no such social or political mechanisms to allow for closure to scientific debates. Since G.E.R. Lloyd's work (1979, 1983, 1987, 1990) has shown that, apart from mathematics, ancient science was not monolithic but rather diverse and varied in that there was no single agreed-upon result or methodology, the ancient scientific debate does not have closure in the same way that social constructivists claim that modern science has closure. We observers therefore make a historiographical mistake to debate about the stability of ancient science using the modern equivalence of stability with closure.

Since stability as closure is foreign to Greco-Roman antiquity, to speak of the stability of successful science in antiquity means almost exclusively to speak in terms of social groups. A thick description of a social group means describing the composition of the group, its members' social relations to each, the group's continuity in time and space, the linguistic and rhetorical practices of the group. For example, we have seen in chapter 4.1.2 and 4.3.2 the stability of the Empiricist sect produces an asymmetrical debate with

[32] Netz (2004a) is a different tracing of the historical contingency of Greek mathematics by diachronically following a single mathematical problem from Archimedes to his deuteronomic commentators to medieval Arabic mathematicians. The formal geometric approach of Archimedes gives way to an informal algebraic manipulation of medieval Arabic mathematicians.
[33] See Shapin (1994).

the Rationalists. More research is needed to detail a thick description of the various scientific social groups in antiquity to explain the stability of their scientific practices.

5.3 CONCLUSIONS

The present study has pursued the ethnographic category of newness in science, emergence, the opposite of closure. We have seen that the emergence of new concepts and objects in Hellenistic period science can result from the appropriation of one science into another; and the resulting object or concept carries with it ideological consequences for the domain of the group of scientists into which it is introduced.

In chapter 1.1 I noted that the ancient Greeks did not have a particular word equivalent to modern Western 'science,' the activity of investigation; they do however speak of *physis*, 'the natural order,' as the object of their investigation. In an important essay, Lloyd (1991b) argues that *physis* was invented as a regularized category during the Classical period in the polemic between natural philosophers (a category including scientists and philosophers) and their opponents, traditionalist healers and diviners. Nature became naturalized, so to speak. The historically-contingent *physis* of philosophers and scientists may have been a regular and normativized category but was still not a singular one: thinkers on *physis* disagreed with each other about the appropriate methodologies to study *physis*. On the grounds of Lloyd's argument it seems more appropriate to speak of 'sciences' and 'natures' in the Classical period. Thus the starting point of *this* study has been to assume the division between and within sciences by 300 BCE.[34] The question we posed was: why then do some Hellenistic scientists appropriate theories from a foreign field for their science?

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[34] Flemming (2000: 11) has interpreted the scientific world of the Hellenistic period in light of Lloyd's argument: "Nor does *physis* (or its Latin equivalent, *natura*) ever escape from the framework of difference and dissent in which it was forged. In the half-millennium between these pioneering thinkers and writers [*viz.* the Classical period philosophers and scientists] and the period of concern in the present study [*viz.* the Imperial period], the terms of these disputes shifted and settled down, but they were never resolved, either philosophically or medically. The diverse philosophical and medical systems and schools that were established and variously developed and dissolved in the intervening centuries each had their own methodologies and (as far as was then allowed) their own physics, together with the either ethically or more corporeally therapeutic programmes with which they were associated." Flemming describes associated groups of thinkers whose philosophical interests provide the metaphysical framework for their science; the lack of philosophical agreement between schools for the most part prohibits interaction between the sciences of the various philosophical schools. Hence to Flemming 'sciences' and 'natures' are created as a

Herophilus and Archimedes appropriate concepts from other scientific domains in strategies of naturalization. The phenomena of Aristoxenian musical rhythm from which Herophilus' materio-semiotic pulse emerges are located in *physis*. Archimedes' mechanical way of seeing mathematical objects emerges from multiple discourses but marks the mechanical contribution to the process, the science located in *physis*. The integration of elements from the domain of one science into another forges a new link between an area of *physis* and a scientific domain not traditionally associated with it. The enlarged networked structure of scientific domains increases the sense of natural regularity and normativity Lloyd (1991b) pointed to as "the invention of nature." Herophilus and Archimedes are thus expanding their scientific community's understanding of *physis* beyond its formulation. Flemming (2000) suggests that the essence of nature is its givenness, what is objectively so: "It is this which gives nature its inherent causal efficacy and authority, of whatever precise kind and in whatever exact quantity."[35] Since what the givenness of nature contains is historically contingent, Herophilus' and Archimedes' strategies of naturalization mark a deeper understanding of the Greek cultural sense of *physis* as a regularized category. The emergence of new science in the Hellenistic period via naturalization marks connections between previously separate areas of *physis*. Thus some category of 'science' did exist in Greek thought of the Hellenistic period which crossed several knowledge domains and this concept of 'science' was a certain kind of knowledge production concerning the natural world.

Yet this aspect of 'science' remains limited in its conception and application in the Hellenistic period. Both Archimedes and the Empiricists, as described in chapters 3.3 and 4 respectively, ultimately reject the ideological consequences of connections within *physis*. I argued in 1.2 that their rejection is founded on a scientific methodology which does not aim for greater certainty: I suggested that there were separate causal *explanatia* for scientific aim and scientific methodology in Hellenistic period science. Since naturalization as a methodological strategy was not accepted by all social groups in

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result of philosophical orientation toward *physis*. Flemming's description of Hellenistic period science corresponds to French's demand for an account of Greco-Roman science derived from philosophy.

[35] Flemming (2000: 17).

Hellenistic science, Hellenistic science as a whole did not achieve closure about whether naturalization was an appropriate methodological strategy. Closure in Hellenistic science, as suggested in 5.2, existed only within particular social groups. Therefore the separate historical *explanatia* of scientific aim and scientific method exist only within particular social groups in Hellenistic period science. There is a need to analyze specific conditions.

The Empiricists, for one, rejected naturalization as a strategy because they held a skeptical philosophy that nature was ultimately unknowable. Perhaps more importantly, the Empiricists rejected the Rationalist strategy of naturalization because it seemed to have neglected the doctor's care-giver role, as argued in 4.2.3. The Empiric tripod and sign-association emphasize the individual doctor's authority in treating patients. The Empiricists rejected a naturalist methodology which provides greater certainly in favor of a methodology which promotes a cultural definition of the individual scientist.

This study has therefore analyzed the *explanans* of scientific methodology within individual social groups; it has not attempted to analyze the *explanans* of scientific aim, while assuming its existence. I suggest that the dichotomy between these two *explanatia* arises from whether the location of the social *explanans* lies within the social group or outside of it.[36] In other words, this study has conducted an evaluation of scientific methodology, the *explanans* internal to the social group of scientists. The *explanans* of scientific aim must lie outside of the social group of scientists in broader culture.

Since the analysis of this study has been limited to social phenomena within the scientific community, further research should consider the social context outside of the scientific community when analyzing the phenomena of cross-scientific appropriation. I argued in chapter 1.2.3 that the historical actors who introduce new concepts and objects into their scientific domain are elite scientists; I also noted in 1.2.3 that Herophilus' and Archimedes' scientific work was sponsored by Hellenistic monarchs. I hypothesize that Hellenistic courts serve as the social sites of legitimation for emerging science utilizing the phenomena of cross-scientific appropriation. Correspondingly, the Empiricist

[36] Shapin (1992) is a helpful summary of the sometimes submerged internalism/externalism debate in the historiography of science.

rejection of the ideological consequences of innovative science might be motivated by a social *explanans* in popular culture outside of the court context. The whole story of the phenomena of cross-scientific appropriation and their resulting ideological consequences has not yet been told.

Appendix A

Galen's Charts of Pulse *Differentiae*

Galen's writings shape the way that the historical record of Hellenistic period medicine is written. Our knowledge of pulse theory in Greek medicine is based on twelve treatises dedicated to the pulse: Galen's *On Pulses to Beginners*, *On Differentiae of Pulses*, *On Distinguishing Pulses*, *On Causes in Pulses*, *On Prognosis Of Pulses*, *Synopsis on Pulses*, *On the Use of Pulses*, [Galen] *On Pulses to Antonius philosopher and eager student*, [Galen] *Medical Definitions*, [Rufus of Ephesus] *On Pulses*, Ps.-Soranus *On Pulses*, and Marcellinus *On Pulses*.[1] Nine of the twelve extant treatises on Greek pulse theory come from the Galenic corpus. Heinrich von Staden's (1989) collection of the fragments of Herophilus collects 44 fragments related to pulse theory, drawn mostly from Galen.[2] Galen's interest in pulse-theory therefore shapes our perception of Herophilus' interest and activity in pulse-theory.

Consider then several different historiographical arguments for how our Galenic text may shape knowledge of Herophilus. First, since Galen often records his admiration for Herophilus' work on pulse theory,[3] the Galenic system and account of pulse may be an enlargement or extension of Herophilus' work. This strategy rightly posits Herophilus as the origin of the tradition of ancient Greek medical discourse on the pulse and locates Galen within that tradition. Yet the evidence shows that the ancient tradition of pulse theory is hardly monolithic: while Galen possibly follows Herophilus in many respects, he is also critical enough of Herophilus for us to suppose that Galenic pulse-theory is not simply a revised system of Herophilus' doctrines.[4] Secondly, Herophilus' doctrines may have reached Galen through intermediaries: Galen often transmits Herophilean doctrines in connection with the Pneumatist doctor Archigenes (*fl.* 110 CE) and a later Herophilean

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[1] Schöne (1907: 448).

[2] Thirty-five of the forty-five fragments von Staden (1989) assembles concerning Herophilus' pulse theory, Herophilus frr. 144-188b vS, are from Galen's pen.

[3] Cf. Herophilus frr. 147, 160, 166 vS.

[4] Cf. Herophilus frr. 173, 176 vS.

doctor Aristoxenus (*fl.* 1-50 CE?). The 19th century German scholars Hermann Schöne and Marcus Wellman developed extensive arguments about Galen's *Quellen* for his writings on pulse which employ these two physicians as primary witnesses to Herophilus' writings.[5] These two earlier physicians may have been reliable witnesses to Herophilus' work but their work is not extant. Yet even with *Quellenforschung* a historian cannot escape's Galen's editorial decisions: our knowledge of Archigenes and Aristoxenus is filtered through Galen's writing. If we wish to suggest a coherent context in which to read the fragments of Herophilus' work on the pulse, we must be conscious first of Galen's interests and aims in pulse theory. I will therefore outline Galen's pulse theory, developing by contrast with Galen's ideas a context for my reading of Herophilus' fragments in chapter 2.

A serious study of Galen's pulse theory would constitute a complete monograph;[6] the following is an outline of my own impressions from my reading of *On Pulses to Beginners*, *On Differentiae of Pulses*, *On Distinguishing Pulses*, *Synopsis on Pulses*, and *On the Use of Pulses*. The overwhelming theme that emerges from Galen's writings on pulse is his interest in classification with an eye to diagnosis and prognosis.[7] Galen

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[5] See von Staden (1989: 284n. 156, 286-7) on Wellman's thesis about Archigenes' use of Herophilus and (1989: 560-2) on Schöne's arguments about Galen's appropriation of Aristoxenus' writings.

[6] The extended treatments of Galen's pulse theory are Deichgräber (1984), who loosely focuses on Galen's self-presentation in *de dignoscendis pulsibus* 1, Harris (1973: 397-431), who attempts simply to express a composite of Galen's theory in English and to that end paraphrases many Greek passages, Barton (1994b: 152-63), who is interested in the social context of scientific prognosis in the Second Sophistic, and Asper (2007: 329-351), who is interested in the contrast of authorial voice between Galen's isagogic pulse literature and "System-pragmatie." Asper (2007: 356-63), considering stronger and weaker scientific authors according to Harold Bloom's theory of anxiety of influence, interestingly compares the manner in which Galen in doxographical sections of his larger treatises promotes his work, suggesting that it is part of Galen's aim to elide the contributions of earlier authors; in Galen's works on pulse theory Asper suggests that the Pneumatist Archigenes is the strong predecessor Galen attempts to overcome.

[7] Hankinson (2008: 16-17) in a recent overview of Galen's work has a similar view: "[Galen's] approach [to pulse theory] consisted of a rigorous classification of pulse-types, according to their size (the extent of the dilation of the vessel, specified in each of the three dimensions if length, breadth, and depth), their speed (how rapidly the diastole is accomplished), their strength, the hardness or softness of the vessels themselves, frequency (interval between pulses), and whether the pulse is consistent or not, and if not whether even in its inconsistency it exhibits some regularity; moreover, recurrent types of pulse are given evocative names: the 'gazelle-like', the 'ant-like', the 'worm-like' and suchlike. Evidently, there is a very large number of possible permutations among these variables, although not all of them are diagnostically and therapeutically relevant. But, Galen thinks, it is possible with long practice (which is necessary in

describes a classification based on eight generic *differentiae* between pulses: size of the artery's movement, speed of the artery's movement, strength of the artery's movement, hardness of artery's tunic, frequency of arterial beat and pause, the regularity of the arterial beat,[8] the fullness of the body of the artery, and the ratio of the time of dilation to the time of contraction.[9] Galen reinforces the classifications of the text with multiple charts of species variation within the generic variation. We should think of the charts as an integral component of Galen's pulse theory.[10] As the summary of Latour (1987) in chapter 1.4 showed, charts and figures are *the* reference points for a technical paper: "Belief in the authors' *word* is replaced by the inspection of 'figures'."[11] The reader is referred to visual presentations under the rhetoric of clarifying the text; nonetheless the experimental evidence presented in Greek science is not intended to discriminate between theories but solely to support the author's viewpoint.[12] In the case of Galen's pulse theory, the text of *On Differentiae of Pulses* includes arterial movement in three dimensions, binary poles of qualitative measurements (a third space is saved for the normative mean), and a temporal duration of the artery at motion and at rest.[13] The charts are predicated on these options and no other.[14] The charts embody the categories of

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order to hone one's sense of touch to detect minute variations: Galen tells us how he trained himself to be able to perceive the faint trace of the arterial systole, which others had said was indiscernible) and experience to discern which particular pulses are associated with what physical conditions, how they vary with age, gender, physical condition and season, how they are affected by emotional states and how various environmental and ingestive factors typically affected them, which in turn leads to being to use them as early warning signs of determinate unhealthy states."

[8] These six in Galen *de pulsibus ad tirones* 2-7, 8.455-59K.

[9] These additional two in Galen *de pulsuum differentiis* 1.3, 8.501K.

[10] So also Asper (2007: 347): "Das Kernstück seiner Lehre, die Zuordnung der 27 einfachen Pulse zu ihren Merkmale nach drei Diastasenklassen wird in der Form eines διάγραμμα gegeben."

[11] Latour (1987: 47).

[12] The important contributions to the debate are von Staden (1975), Lloyd (1979: 221-25, 1991a).

[13] Galen *de pulsuum differentiis* 1.3, 8.500-501K.

[14] Asper's (2007: 347-8) description of the charts is therefore correct as a rhetorical description: "Die Tabelle entlastet dabei den Text." Asper's (2007: 337-343) distinction between "Primärdiskurs" and "Meta-Disurks" of *de pulsuum differentiis* (books 1 and 2-4, respectively) is an important rhetorical divide. However, the rhetorical features Asper (2007: 348) identifies with the charts – "Der Text kann vollständig dekontextualisiert werden and wird damit autonom" – lead to important conceptual consequences in *pulse theory itself*. A decontextualized description of a pulse from Galen's chart may remove the name of the pulse (e.g. μέγας, μικρός) and its neighboring descriptions but it leaves the *differentiae* with which the pulse is located in the chart unquestioned: the Galenic categories of dimensionality or binary qualitative

Galenic discourse about the pulse.

After summarizing the contents of one chart Galen remarks on the uselessness of attempting to name all the combinations when a description itself is enough to classify the pulse-type.[15] The charts and Galen's attitude toward names proper suggest that he regards the species information of various charts sufficient to identify a pulse. Galen's classification is therefore deliberately exhaustive: a physician needs no more than the eight generic *differentiae* and the enumerated *species* to classify and identify a pulse; all possible sphygmological phenomena are accounted for and can be located within the dialectical matrix of Galen's charts.

Furthermore it is part of Galen's self-presentation to oppose elements of his method to Herophilus'. In a long and important chapter at the end of book 3 of *On Distinguishing Pulses* Galen considers the question of rhythm of the pulse, the comparison of the time of the dilation to the time of the contraction.[16] Rhythm requires speaking accurately of time and having a sense of time in regards to pulse requires perception of the entirety of the motion of the artery; but the problem, as Galen sees it, is that the entirety of the arterial motion is not perceptible: the first parts of motion of the dilation and the final parts of the contraction are imperceptible.[17] Nevertheless, if only the final part of the dilation can be perceived, that provides an ability to infer (*συλλογισμός*) its quantity, namely the quantity of the interval between dilation and contraction.[18] Yet this too is not assured since there are further complications due to the type of pulse: for example, in vehement pulses (*σφοδροῖς σφυγμοῖς*) squeezing an artery moderately allows a recognition of its initial parts of motion but not of its interval. The combination of practical problems and theoretical need leads Galen to suppose that only in vehement pulses can we actually speak accurately of rhythm, a solution which is

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measurement remain attached as formative descriptions. Therefore the rhetorical divide of "Primärdiskurs" and "Meta-Disurks" is still only a measure of the self-reflection that Galen intends *the reader* to carry to the subject of the text, not necessarily the self-reflection that Galen himself brings to the text.

[15] Galen *de pulsuum differentiis* 1.4, 8.507-8K. See **text 1** below.

[16] Galen *de dignoscendis pulsibus* 3.3, 8.902-16K. Translated as **text 4** below.

[17] Galen *de dignoscendis pulsibus* 3.3, 8.903K.

[18] Galen *de dignoscendis pulsibus* 3.3, 8.903-4K.

unsatisfactory.[19]

Galen presents his solution to the problem of rhythm at the very end of the book 3 of *On Distinguishing Pulses* in another chart.[20] Each dilation and contraction is measured relatively, from whatever part of it can be perceived by touch. The Galenic doctor rates the dilation fast, moderate, or slow and does likewise for the contraction; the combination of both arterial motions are then located among those on the chart. The doctor thus avoids the problem that Galen initially identified: to measure the entirety of arterial motion is to measure the ratio of time length of each dilation and contraction. But in Galen's method there is no need to measure the entire motion of the dilation and contraction, since any perceptible part is taken to stand for the whole. Given an even and regular pulse, the chart is applicable for any pulse except the dullest, the parts of whose contraction are not perceptible.

Galen lists three different possible solutions to the problem of rhythm, depending on whether the doctor believes that the contraction is perceptible to touch.[21] These solutions Galen also dismisses, because they either ignore dilation or limit the usefulness of rhythm by taking the perceptible part of dilation in relation to all the remaining parts, namely contraction and the two rests. Galen gains no aid from the tradition of pulse-theory because Herophilus' words on rhythm are unclear.

> *αὐτὸς δὲ ὁ Ἡρόφιλος πολλαχόθι μὲν ῥυθμῶν εἰς τὰς προγνώσεις μνημονεύει, χαλεπὸν μὴν ἐξευρεῖν τί ποτε καὶ λέγει τὸν ῥυθμὸν, ἆρά γε τὸν λόγον τοῦ τῆς διαστολῆς μόνου χρόνου πρὸς τὸν τῆς συστολῆς μόνης, ἢ καὶ αὖ τὸν τῆς ἑπομένης ἑκατέρᾳ τῶν κινήσεων ἠρεμίας προσνέμει. καὶ διὰ τοῦτο οὐδὲ τοῖς ἀπ' αὐτοῦ κληθεῖσιν Ἡροφιλείοις ὁμολογεῖται, τί ποθ' ὑπὲρ αὐτῶν φρονεῖ γε ὄντως. οὔτε γὰρ ἡ λέξις αὐτοῦ θάτερον ἐνδείκνυται σαφῶς οὔθ' ἡ τῶν πραγμάτων φύσις ἱκανὴ πιστώσασθαι.*
>
> Herophilus himself many places mentions rhythms for the purpose of prognoses yet it is difficult to discover just how he means 'rhythm', whether at least as the ratio of the time-unit of the dilation alone to the time-unit of the contraction alone or does he attribute moreover the <time-unit> of the following rest to each of the motions. For this reason there is not even agreement among those called Herophileans after him, in regards to whatever he at least really thought about

[19] Galen *de dignoscendis pulsibus* 3.3, 8.907K.
[20] Galen *de dignoscendis pulsibus* 3.3, 8.914-6K.
[21] Galen *de dignoscendis pulsibus* 3.3, 8.909K.

> these things. For neither do his words indicate clearly which of the two nor does the nature of the matter suffice for confirmation.[22]

Herophilus aims to use rhythm in pulse doctrine for prognosis. Galen wants to consider rhythm for the purposes of prognosis but believes the terminology of the Herophileans of beats and parts is more confusing than illuminating.[23] But since Herophilus' words on rhythm do not help to determine whether to include or exclude the rests accompanying dilation and contraction and thereby what numerator and denominator the ratio of the pulse-rhythm ought to be, Galen puts tradition aside to develop his charts.

Galen thus presents himself as a reviser of the Herophilean tradition of pulse rhythms which is founded on a musical terminology of "up-beats" and "down-beats" in rhythm. Like Herophilus, the originator of the Greek pulse tradition, Galen accepts that 'rhythm' is an acceptable category to describe the pulse and that the purpose of the description is its use for prognosis. Galen nonetheless problematizes the tradition: Was there a rest between the beats? If so, did Herophilus feel them too? Yet not the entirety of dilation and contraction can be felt in every pulse. Galen claims that the categories embodied in his charts solve the problems inherent in Greek pulse tradition.

Therefore I give here a selection of the most important evidence about Galen's categories of the pulse: Galen's pulse charts. In *On the Differentiae of Pulses* Galen offers four charts of pulse *differentiae* in three different sections of text; in *On Distinguishing Pulses* Galen offers a further chart. I print first the chart of the *differentiae* in Greek according to Kühn's edition and then a translation of the surrounding context of text and the chart within the text.

Text 1: Galen *de pulsuum differentiis* 1.3-1.4, 8.500-508K

Chart:

α′	μακρὸς	πλατὺς	ὑψηλὸς	μέγας
β′	μακρὸς	πλατὺς	σύμμετρος	
γ′	μακρὸς	πλατὺς	ταπεινὸς	
δ′	μακρὸς	σύμμετρος	ὑψηλὸς	

[22] Galen *de dignoscendis pulsibus* 3.3, 8.911-2K = Herophilus fr. 173.4-12 vS.
[23] Galen *de dignoscendis pulsibus* 3.3, 8.912K.

ε′	μακρὸς	σύμμετρος	σύμμετρος	ἰσχνὸς	
ϛ′	μακρὸς	σύμμετρος	ταπεινὸς	ἰσχνὸς	
ζ′	μακρὸς	στενὸς	ὑψηλὸς		
η′	μακρὸς	στενὸς	σύμμετρος	ἰσχνὸς	
θ′	μακρὸς	στενὸς	ταπεινὸς	ἰσχνὸς	
ι′	σύμμετρος	πλατὺς	ὑψηλὸς	ἀδρὸς	505
ια′	σύμμετρος	πλατὺς	σύμμετρος		
ιβ′	σύμμετρος	πλατὺς	ταπεινὸς		
ιγ′	σύμμετρος	σύμμετρος	ὑψηλὸς		
ιδ′	σύμμετρος	σύμμετρος	σύμμετρος	μέσος	
ιε′	σύμμετρος	σύμμετρος	ταπεινὸς		
ιϛ′	σύμμετρος	στενὸς	ὑψηλὸς		
ιζ′	σύμμετρος	στενὸς	σύμμετρος		
ιη′	σύμμετρος	στενὸς	ταπεινὸς	ἰσχνὸς	
ιθ′	βραχὺς	πλατὺς	ὑψηλὸς	ἀδρὸς	
κ′	βραχὺς	πλατὺς	σύμμετρος	ἀδρὸς	
κα′	βραχὺς	πλατὺς	ταπεινὸς		
κβ′	βραχὺς	σύμμετρος	ὑψηλὸς	ἀδρὸς	
κγ′	βραχὺς	σύμμετρος	σύμμετρος	ἀδρὸς	
κδ′	βραχὺς	σύμμετρος	ταπεινὸς		506
κε′	βραχὺς	στενὸς	ὑψηλὸς		
κϛ′	βραχὺς	στενὸς	σύμμετρος		
κζ′	βραχὺς	στενὸς	ταπεινὸς	μικρὸς	

Translation:

| 500 1.3 Since the body of the artery is concave and long and spherical, and moves entirely in a double motion composed from opposite parts, either it collapses into itself from every direction or dilates in every direction, and this doubled motion is called pulse, it is necessary that two rests occur in it in each case: one is after the moment of dilation before contraction begins, the second is after the moment of contraction before dilation begins. The touch of experts recognizes these two rests and reason proves nothing less. For before the previous motion ceases, the artery would not begin the opposite motion. Indeed ceasing is to hold position and be at rest. Therefore there is rest between the motions. Therefore it is entirely necessary that there be some time-unit of the motions themselves particular to each, | 501 and a time-unit of the rests, again particular to these. Since the artery has three dimensions, just as any other body – length and breadth and depth – it is entirely necessary that in each of the dimensions there be some quantity of dilation and contraction. It is further necessary that it have tension, either weak and faint, or readily and strongly active; and that the tunic itself of the artery either be soft or

hard, but that the internal width either be empty somehow or full; and that in all these things there occurs at some time a regularity and at some time an irregularity; and that there be some ratio of the time-unit of the dilation to that of the contraction; and that beyond these no other *differentia* can occur in one pulse. For it is necessary to examine the time-unit of the motions or the rests, or the quantity of the dimensions through which they move, or the quality of the activity, or [the quality] of the tunic of the artery or of its concavity, or [the quality] of how comparable things are relative to each other (they can obviously be the same kind of things) – [so] all these things have been said and | 502 nothing is left out of the account in any way but all these *differentiae* of the *genera* in one pulse have now been said. There are two more so-called systematic *differentiae* according to which pulses are comparable with each other, and we mean regularity and irregularity, and order and disorder.

1.4 The *differentiae* by species are many more than each of the genera, which we already covered, having begun from the genus according to motion itself. For it is necessary that the motion either be moderate and natural or have become somehow faster or somehow slower, so that all the *differentiae* of pulses are three according to genus: fast, which happens as the artery moves in little time; slow, as the artery moves in much time; and moderate, as the artery moves in moderate time. The *differentiae* of pulses according to the quantity of dilation are nine in number considered according to one dimension in each of three dimensions. According to the length of the artery, what is moderate in it and what exceeds its length or falls short: | 503 the pulse that exceeds is called long, the pulse that falls short is called short. According to the breadth there is the moderate in it and the two immoderates: the pulse over the moderate is called broad and the pulse opposite it is narrow. Likewise in the dimension by depth there will be the moderate pulse, the lofty pulse, and the lowly pulse. These nine *differentiae* of pulses considered in one dimension, and the *differentiae* of pulses in the three dimensions together are twenty-seven. You will understand these things clearly from the chart, for one will be both long and broad and lofty; let it have been written first of all. Another will be both long and broad and moderate in depth; let it have been written second. Another will be long and

broad and lowly; let it have been written third. Following them all the remaining pulses will be recognized by similar means, since two of the original dimensions will remain the same as the third, the last changes: e.g. so the fourth will be long and moderate in breadth and lofty; the fifth will be long and moderate in breadth and moderate in depth; the sixth will be long and moderate in breadth and lowly; and then the other three again, the first dimension staying long, | 504 the second dimension staying narrow, and the third changing three times. These are nine, the first dimension remaining long in respect to length, the other two changing variously. There will be a subsequent nine, as the first dimension remains moderate in length and the rest change. And again nine more, as the first dimension remains short in respect to length, the rest changing.

1	long	broad	lofty	great
2	long	broad	moderate	
3	long	broad	lowly	
4	long	moderate	lofty	
5	long	moderate	moderate	weak
6	long	moderate	lowly	weak
7	long	narrow	lofty	
8	long	narrow	moderate	weak
9	long	narrow	lowly	weak | 505
10	moderate	broad	lofty	strong
11	moderate	broad	moderate	
12	moderate	broad	lowly	
13	moderate	moderate	lofty	
14	moderate	moderate	moderate	medium
15	moderate	moderate	lowly	
16	moderate	narrow	lofty	
17	moderate	narrow	moderate	
18	moderate	narrow	lowly	weak
19	short	broad	lofty	strong
20	short	broad	moderate	strong
21	short	broad	lowly	
22	short	moderate	lofty	strong
23	short	moderate	moderate	strong
24	short	moderate	lowly	| 506
25	short	narrow	lofty	
26	short	narrow	moderate	
27	short	narrow	lowly	small

There are these twenty-seven pulses in quantity occurring in three dimensions at the same time. Two of them have names agreed upon by everyone, the first and the last in the list. The one is called great, the other small, but all the rest have no amount. For neither the so-called weak nor strong pulses make clear one kind of thing of those from the chart but they are classed by many generically. For in those cases where the dimension in length surpasses to the two remaining, they call all these weak. In those cases where the remaining surpasses this dimension, they call them strong on the other hand. Therefore both the fifth and the sixth pulse in the chart, and still in addition to them the eighth and ninth and the 18th are called weak, opposite them as strong are the tenth pulse in the chart and the nineteenth and the twenty | 507 -second and the twenty-third. These names are more generic and common to many. They already call these same pulses alternately, light [*lepton*] for weak and thick [*pachyn*] for strong. Nor do we have a name proper for the pulse moderate in three dimensions, which alone in the twenty-seven is natural [*kata physin*]. We make this clear by speech, either saying that the pulse is moderate in the three dimensions, or is medium of great and small, or is natural [*kata physin*] in the quantity of dilation, or however in a different way we hope that what is said will be clear. Therefore it occurs to me to be amazed at those clever only in names, who always seek what <name> it is necessary to call some pulse – unless they should cease from strife for this reason, when they see that many pulses do not have a particular name and that this doesn't hurt their teaching [*didaskalian*] so long as they are still able to make clear their meaning in a description [*logō*]. Well then, for some to name a pulse short and narrow and lowly is like saying that there is a bipedal animal. In this case here the description [*logos*] is "bipedal animal" but the name of the thing [*pragmatos*] of which | 508 the description is is "man", so also in pulses the name is "great", but its description [*logos*] is "long and broad and lofty." And again the description of another pulse is short, broad, and lowly but it has no name. Yet we will speak again about these matters.

Text 2: Galen *de pulsuum differentiis* 1.15, 8.530-537K

Charts:

α′	ταχὺς	βραδὺς
β′	ταχὺς	ταχὺς
γ′	ταχὺς	σύμμετρος
δ′	βραδὺς	βραδὺς
ε′	βραδὺς	ταχὺς
ϛ′	βραδὺς	σύμμετρος
ζ′	σύμμετρος	βραδὺς
η′	σύμμετρος	ταχὺς
θ′	σύμμετρος	σύμμετρος

and

α′	ταχὺς	ταχὺς	βραδὺς	
β′	ταχὺς	ταχὺς	ταχὺς	
γ′	ταχὺς	ταχὺς	σύμμετρος	
δ′	ταχὺς	βραδὺς	βραδὺς	
ε′	ταχὺς	βραδὺς	ταχὺς	
ϛ′	ταχὺς	βραδὺς	σύμμετρος	
ζ′	ταχὺς	σύμμετρος	βραδὺς	
η′	ταχὺς	σύμμετρος	ταχὺς	
θ′	ταχὺς	σύμμετρος	σύμμετρος	
ι′	βραδὺς	ταχὺς	βραδὺς	
ια′	βραδὺς	ταχὺς	ταχὺς	| 534
ιβ′	βραδὺς	ταχὺς	σύμμετρος	
ιγ′	βραδὺς	βραδὺς	βραδὺς	
ιδ′	βραδὺς	βραδὺς	ταχὺς	
ιε′	βραδὺς	βραδὺς	σύμμετρος	
ιϛ′	βραδὺς	σύμμετρος	βραδὺς	
ιζ′	βραδὺς	σύμμετρος	ταχὺς	
ιη′	βραδὺς	σύμμετρος	σύμμετρος	
ιθ′	σύμμετρος	ταχὺς	βραδὺς	
κ′	σύμμετρος	ταχὺς	ταχὺς	
κα′	σύμμετρος	ταχὺς	σύμμετρος	
κβ′	σύμμετρος	βραδὺς	βραδὺς	
κγ′	σύμμετρος	βραδὺς	ταχὺς	
κδ′	σύμμετρος	βραδὺς	σύμμετρος	
κε′	σύμμετρος	σύμμετρος	βραδὺς	
κϛ′	σύμμετρος	σύμμετρος	ταχὺς	
κζ′	σύμμετρος	σύμμετρος	σύμμετρος	| 535

Translation:

| 530 1.15 Therefore having said sufficiently that, of the pulses unequal in one part, whenever they make their irregularity equal, there are six *differentiae* total and that we have not found any of these kind ending either from the slowest motion to the fastest or from the fastest to the slowest, let us speak about the unequal pulses already making their

turning [sc. from slow to fast or vice versa]: in these there clearly seem to be sometimes two, sometimes three differences of motion. For me sometimes a fourth difference appeared dimly. Perhaps someone training at length and attending to the matter and practicing his touch might be able to recognize four differences. | 531 But now we will speak about those things that occur clearly and often both to me and to those who have honed their skill regarding pulses, whenever the motion of the artery makes either two or three perceptible differences: for if there are two differences, there will be six figures of combinations; if three, there will be twenty-four combinations. Why then since there are three pulses in each of the differing motions – swift, slow, and moderate – do I not say that there are nine *differentiae* from their combination but six, you may learn if you recognize that, by supposing that the same pulse happens twice (no rest coming between them), it makes one equal whole. For this reason three of the nine combinations no longer qualify <as pulses> in which there is not still an unequal pulse, but rather <there is> an equal pulse, whether fast or slow or moderate, as is clear in the chart. For the second pulse in it and the fourth and the ninth become equal, the second is fast, the fourth is slow, and the ninth is moderate. If there is some difference of these <speeds> in relation to themselves – the fast to the fast, or the slow | 532 to the slow – let it be ignored at present. For it will present a greater unclarity. But in the case of the same <speeds> and those <speeds> equal to each other let the present discourse come to an end.

1	fast	slow
2	fast	fast
3	fast	moderate
4	slow	slow
5	slow	fast
6	slow	moderate
7	moderate	slow
8	moderate	fast
9	moderate	moderate

And so, if, supposing three motions differing with each other and changing pulses in each

of the three <motions>[24], you would conjugate them, | 533 there will be twenty-seven figures and three of them will necessarily coincide in equality. This too is clear in the chart.

1	fast	fast	slow	
2	fast	fast	fast	
3	fast	fast	moderate	
4	fast	slow	slow	
5	fast	slow	fast	
6	fast	slow	moderate	
7	fast	moderate	slow	
8	fast	moderate	fast	
9	fast	moderate	moderate	
10	slow	fast	slow	
11	slow	fast	fast	
12	slow	fast	moderate	| 534
13	slow	slow	slow	
14	slow	slow	fast	
15	slow	slow	moderate	
16	slow	moderate	slow	
17	slow	moderate	fast	
18	slow	moderate	moderate	
19	moderate	fast	slow	
20	moderate	fast	fast	
21	moderate	fast	moderate	
22	moderate	slow	slow	
23	moderate	slow	fast	
24	moderate	slow	moderate	
25	moderate	moderate	slow	
26	moderate	moderate	fast	
27	moderate	moderate	moderate	| 535

Therefore since three <pulses> are the same in these columns (the second in the chart, and the thirteenth and twenty-seventh), the second will be fast, the thirteenth will be slow, and the last will be medium. Twelve other pulses coincide with the first chart. For two <of them> would be the same to the first pulse from the first chart, the first and the fourth from the second chart, the first has more speed, the fourth more slowness. The

[24] Reading *καθ' ἑκάστην αὐτῶν τῶν τρεῖς σφυγμούς ὑπαλλάττων.*

same as the third [from the first chart] are the third and the ninth, the third has more speed, the ninth more moderation. The same as the fifth [from the first chart] are the eleventh and the fourteenth, the eleventh has more speed, the fourteenth has more slowness. The same as the sixth [from the first chart] are the fifteenth and the eighteenth, the fifteenth has more slowness, the eighteenth has more moderation. The same as the seventh [from the first chart] are the twenty-second and the twenty-fifth, the twenty-second has more slowness, the twenty-fifth has more moderation. The remaining two from the second chart, the twentieth and twenty-sixth, are the same as the eighth from the first chart, the twentieth has more speed, the twenty-sixth has more moderation. There would be controversy here, if there were two different motions in the dilation, because some would set all such pulses into the earlier | 536 chart, yet others would calculate their magnitudes and thus, if they were equal, set them into the earlier chart, but if one pulse was double, into the second chart. I would try to judge the battle if I had hope for some gain. But since it suffices to define them to this degree, namely that sometimes one of the motions is carried from a greater distance, sometimes the other, or even both evenly, let someone mentioning this set the aforesaid pulses into whichever of the charts he wishes in order that he may know what meaning each motion has. That the remaining twelve pulses from the second chart, which are unequal in every respect, share nothing in common with those in the first chart is obviously clear; to which the very fact of their inequality is added – not as if the twelve other <pulses> would share [this] with the first chart if they were not unequal, for they are, but rather <it is obvious> that they make clear their inequality in the three *differentiae* of movement, the others having only two *differentiae*, and, to one counting in the order from the first, | 537 they are fifth and 6th and 7th and 8th and 10th and 16th and 19th and 21st and 23rd and 24th.

Text 3: Galen *de pulsuum differentiis* 2.8, 8.615-617K

Chart:

α΄	μακρὸς	πλατὺς
β΄	μακρὸς	σύμμετρος
γ΄	μακρὸς	στενὸς

δ′	πλατὺς	σύμμετρος
ε′	σύμμετρος	σύμμετρος
ς′	στενὸς	σύμμετρος
ζ′	βραχὺς	πλατὺς
η′	βραχὺς	σύμμετρος
θ′	βραχὺς	στενὸς

Translation:

| 615 For this reason we resolved the entire nature [*physin*] of the pulses into the *differentiae* composing its nature, naming the one *differentia* according to the quantity of the dilation, another according to the quality of the beat, another according to the quality of the tunic, and the others which have been said correspondingly. Then again we sought the simple concepts in them in order that, what ratio the *differentia* in quantity of the dilation has to the pulse's whole nature nature composed of all its parts, we would likewise discover something else to that very nature[25] has some similar ratio. For as that genus is a combination of the entire nature of the pulse, so again the genus itself fills each of the dimensions. To conceive simultaneously of two dimensions is not necessary for the filling out of the entire pulse nor for the one dimension in regard to the quantity of the dilation. Therefore discourse about these things is superfluous and we have well passed by them, but Archigenes has treated them poorly, rending them apart as if a dog, and speaks of six conjugations, | 616 and passed by the rest, which are twenty-one. For it is necessary that all the *differentiae* of each of the dimensions be joined to each of the *differentiae* of the rest, so that there is a conjugation of nine *differentiae* in each of the two dimensions and all together are twenty-seven. I record one conjugation, from which it is possible to learn about the remaining <conjugations>.

1	long	broad
2	long	moderate
3	long	narrow
4	broad	moderate
5	moderate	moderate

[25] Reading τι παραπλασίον <λόγον> ἔχον ἄλλο.

6	narrow	moderate[26]	
7	short	broad	
8	short	moderate	
9	short	narrow	| 617

So in this chart we made nine conjugations, combining the three *differentiae* according to length with the three *differentiae* according to breadth. Again, there would be another chart in the same manner having the three *differentiae* of depth joined with the three *differentiae* of length, and also a third chart in which the three *differentiae* of breadth will be joined with the three *differentiae* of depth. And it is obvious that there will be nine conjugations in each of them. Consequently there are twenty-seven conjugations. Therefore it has already become clear that, when even those two were imagined, Archigenes passed over many, just as in even all the rest.

Text 4: Galen *de dignoscendis pulsibus* 3.3, 8.909-916K.

Chart:

διαστολὴ	διαστολὴ	διαστολὴ
ταχεῖα	σύμμετρος	βραδεῖα
ταχεῖα	σύμμετρος	βραδεῖα
ταχεῖα	σύμμετρος	βραδεῖα | 915
συστολὴ	συστολὴ	συστολὴ
ταχεῖα	ταχεῖα	ταχεῖα
σύμμετρος	σύμμετρος	σύμμετρος
βραδεῖα	βραδεῖα	βραδεῖα

Translation:

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[26] So Kühn's text. However we would logically expect the columns of the fourth through sixth rows of the chart to be reversed as follows:

δ′	σύμμετρος	πλατὺς
ε′	σύμμετρος	σύμμετρος
ς′	σύμμετρος	στενὸς

The translation correspondingly would be

4	moderate	broad
5	moderate	moderate
6	moderate	narrow

I cannot explain why the columns in these rows are reversed.

| 909 Therefore, since there are those three opinions about the rhythms in pulses, those from the second opinion will confess that they can say nothing against the aforesaid difficulties, those from the first and third opinions may seem to be well off, the first because they compare the time-unit of the manifest motion to every remaining [time-unit] of what they call rest, the third because they compare the time-unit of the manifest motion together with the time-unit of the rest with them against the remaining time-unit, having made the beginning of the contraction a limit of the composition of the previous two time-units. It is worthy of each to wonder – for the first group, if they speak only about the events of the contraction, | 910 forgetting to speak about the dilation. For in dull pulses we showed that the quantity of the interval in the dilation is knowable by inference [*sullogismos*] but that the time-unit of the motion is indistinguishable, since only the ends external to the motion come to perception. I do not know how they claim to compare the time-unit of dilation to all the rest, for the perceptible part of its time-unit is very small, unless they wish in some way to compare this very thing alone to all the rest. The rhythm for them would thus be the ratio of the manifest time of the motion in dilation to all the rest. If they mean this, they claim it is possible in some way but not useful at least, since no prognosis is able to made from such a rhythm in which the time-unit of the manifest part of the contraction is compared to all the rest, [namely] to that composed from the time-unit of the external rest and <the time-unit>[27] of the contraction and, as a third part, the time-unit of the internal rest and, as a fourth part, [the time-unit] of the non-manifest part of the dilation. In addition to the fact that nothing useful can be taken from this teaching, still | 911 these doctors confuse the understanding of rhythm, as if someone pretending to be a musician claimed that rhythm is not a ratio of the time-unit of up-beat to the time-unit of down-beat but the manifest part of the up-beat to every remaining time-unit. Like to them those from the third school are mistaken, thinking it better than the previous group to attribute alone the time-unit of the external rest to the time-unit of dilation, insofar as they forget that the time-unit of the contraction is

[27] Reading καὶ <τοῦ> τῆς συστολῆς.

indistinguishable to perception in dull pulses and thus are likewise tripped up. In the third place they qualify in addition something remarkable, that the primary impulse of the contraction is entirely perceptible, although this is not perceptible in the case of dull pulses. Therefore in all these things necessarily many difficulties occur in sects [*haeresesi*] in the differentiation of rhythms and for this reason I think that those after Herophilus did not try to write something for prognosis from rhythms. Herophilus himself many places mentions rhythms for the purpose of prognoses yet it is difficult to discover just how he means 'rhythm', whether at least as the ratio of the time-unit of the dilation alone to the <time-unit> | 912 of the contraction alone or does he attribute moreover the time-unit of the following rest to each of the motions. For this reason there is not even agreement among those called Herophileans after him, in regards to whatever he at least really thought about these things. For neither do his words indicate clearly which of the two nor does the nature of the matter suffice for confirmation. Therefore if we preserve one of the two opinions, following the musicians, we will attribute time-units of the rests to the time-units of the preceding motions; and if [we preserve] the need for prognosis, comparing motion to motion, we will examine the time-units of the rests individually. Since it is necessary to eliminate one of the two, either to eliminate the thought of the name or to overturn the purpose, we are stuck in a difficult-to-handle conundrum. Nevertheless, since it seems necessary to pick one of them, prefer what is useful for prognosis, despising the name from the musicians. For what will we harm by making prognoses from proportion in respect to the time-unit during the motions though we do not have a name peculiar to it? The art is harmed not in a situation when we are at a loss for names but in situations where we cannot make prognoses. Let it be | 913 therefore for practical purposes that rhythm is established in the ratio of the time-unit of movements, since we will separately make an inquiry in regards to Herophilus' opinion. But when we do this, the difficulty still seems to remain, since not every time-unit of the dilation can be known, except in the most vehement pulses, nor is the beginning of the contraction perceptible in all cases. How therefore was Herophilus first to establish some time-unit in relation to sense-perception, in which he, by measuring all the rest, claimed

that they consist either of two or three or more, or are of perfect units and not-subject-to-increase, as they themselves call them, or units decreased a little or a great degree or the greatest degree? For in the case of all pulses he seems to write as though precisely distinguishing the time-units either of the motions alone or also of the rests with them – for it makes no difference at least to the present difficulty – or if not in the case of all <pulses> but in those in which it is possible, in these alone must he be thought to write such things. So we will perhaps examine this separately later some time. Now the task is not to investigate Herophilus' opinion but to discover what is both true and useful, | 914 we must try to indicate the following clearly, how the matter was discovered as we worked in the procedures themselves. It goes as follows: comparing the quality of the motion in the dilation to the quality of the motion in the contraction we discover nine primary *differentiae* which are clarified in the chart, and in each *differentia* there are many others inexpressible in theory but more or less distinguishable during the observations themselves. What meaning each *differentia* has we will make clear in *On Prognosis*. But now we will first subscribe the chart, since it will be readily clear to those trained in the first book of *On Differentiae of Pulses*. Following we will say in what way again many *differentiae* exist differing from each other in quantity, even if they are of the same kind.

dilation	dilation	dilation
fast	moderate	slow
fast	moderate	slow
fast	moderate	slow | 915
contraction	contraction	contraction
fast	fast	fast
moderate	moderate	moderate
slow	slow	slow

Therefore since the first *differentiae* written in the chart have a fast motion, it indicates that the motion in dilation is spurred on to the greatest degree, and the motion in contraction is greater by a small degree than the moderate and medium motion, or on the

other hand that the motion in dilation is greater by a little, and that the motion in contraction is much greater or both are greater by a little or both by a lot, or the one by a little, the other by a lot, or less by a little or by a lot, or however else. The variety is obvious. It is not possible to say either that this seems not to happen, or that it has no meaning. For indeed it happens and very much has meaning. For us it sufficed to make prognoses from this distinction, since we had no need of primary time-units, both whole in their parts and enlarged. That such a distinction needs no entire | 916 motion but can become clear to anyone through a chance part of it, except if it should be unequal (for then the part is not equal to the whole). Moreover not even in very dull pulses is it possible to employ this method. For it is not possible in the case of these pulses to recognize the first beginning of the contraction, not any part of it is worthy of record.

Appendix B

Archimedes *Ephodos* 426-438

I print here the first 16 columns of the Archimedes Palimpsest's text of Archimedes' *Ephodos*, just until the beginning of the second proposition. Since the palimpsest is the unique witness to the *Ephodos*, there are two challenges: to establish the precise reading of the unique witness and then to emend the text. I am therefore primarily concerned to provide a readable text based on a transcription of the palimpsest as free from doubt as possible, while retaining as much of the formatting of the palimpsest as possible. My text is a composite and reconstructed text, not a transcription of the palimpsest.

The text of the *Ephodos* comes from a single manuscript, the well-known Archimedes Palimpsest.[28] First read by J.L. Heiberg in Istanbul in 1906, the palimpsest primarily contains Archimedean treatises; for *Floating Bodies, Stomachion,* and *Ephodos* it is the unique Greek text. Heiberg read the manuscript *in situ* and took many photographs as evidence for his second edition of Archimedes (1910-15); he refers to it as codex C in his (1913) apparatus. At some point soon after Heiberg's second visit in 1908 the manuscript was lost to scholarly study until 1998 when it was purchased at auction by an anonymous owner, who has allowed scholars to examine and study it. Reviel Netz and collaborators are preparing a new edition of the *Ephodos*; his team's transcription of the palimpsest has been publically available online since October 2008. The palimpsest has fared badly since Heiberg examined it, suffering the loss of several leaves and increased physical deterioration due to mold. On the other hand, technological advances have added new readings to Heiberg's edition of the text.

Since I have not seen the palimpsest, my foundational text is the Netz et al. (2008) transcription, which notes words or endings abbreviated by the palimpsest *per symbolum*. I take the Netz et al. (2008) transcription to be the most accurate transcription of the manuscript whenever transcribed readings are in dispute. Thus at line 285 I write in the

[28] See Netz and Noel (2007) for a history of the codex.

apparatus ἐ<κ>δοθεῖσαν *scripsi* : ἐδοθεῖσαν Netz : ἐ̣κδοθεῖσαν Heiberg – whereby I mean that Netz et al. (2008) has accurately read the palimpsest's ἐδοθεῖσαν to Heiberg's (1913) reading ἐ̣κδοθεῖσαν and therefore I emend Netz et al.'s (2008) transcription (which happens to be Heiberg's (1913) transcribed reading). Therefore, where I prefer Heiberg's (1913) readings, it is because he transcribes the reading demanded by sense.

Still I recognize that the deterioration of the manuscript in the nearly full century since Heiberg read it is a factor in establishing a witness: if Netz et al. (2008) dot or supplement readings where Heiberg (1913) claims to read the manuscript without problem, I print no dots nor angle brackets. Readings given in the apparatus without Latin comment refer solely to the transcriptions of the palimpsest; I refer to the palimpsest as C when both the readings of Heiberg (1913) and Netz et al. (2008) agree and to those individual publications when their transcribed readings disagree; and I note where Netz et al. (2008) and Heiberg (1913) differ on the reading of letters and the length of the line.

I err on the side of bibliographic fullness in recording emendations in the apparatus. Unlike previous writers on the *Ephodos*, I attempt to reconstruct Archimedes' Doric dialect from the Koine of the palimpsest. My goal in reconstruction has been both to harmonize the *Ephodos* text with J.L. Heiberg's reconstructions of other Archimedean texts for which there was manuscript evidence in Doric and to offer a plausible account of several manuscript corruptions.

The *Ephodos* is one of the few Archimedean treatises transmitted purely in Koine. With only a single manuscript as the source for the text, Heiberg (1913) did not attempt to restore Doric forms in the *Ephodos*. Knorr (1989) points out that Heiberg (1910-15) takes a lower frequency of Doric forms to be evidence for a higher degree of ancient editorial activity and this would put *Ephodos* in the mostly heavily edited group of texts: *Measurement of the Circle, On the Sphere and Cylinder,* and *Equilibrium of Planes*.[29] The *communis opinio* is that these texts were the school texts of late antiquity and the early Byzantine period (the focus of late ancient commentators like Eutocius), a

[29] Knorr (1989: 808).

surprising place to find the *Ephodos*, which demands much more mathematical skill of the reader. But the Theodosius φιλόσοφος who wrote a commentary on it according to Suda θ 142 is Theodosius of Bithynia *fl.* 100 BCE, known for his *Spherics*, and not a Byzantine writer.[30] Moreover, it seems unlikely if *Ephodos* was part of the school texts of late antiquity and the early Byzantine period that only one palimpsested manuscript would have survived.

I suggest that the text was edited into Koine in antiquity when Theodosius published a commentary on the *Ephodos*. Modern scholarship has developed a certain artificial polarity between ὑπομνήματα and συγγράματα to mean, respectively, a continuous line-by-line commentary and a monograph treatise on thematic elements, often called περί-literature for the form taken by titles. Pfeiffer (1968) is a typical viewpoint,[31] although the evidence is hardly unanimous as Harding (2006) points out.[32] Deas (1931) made the useful suggestion, ignored by Harding's survey, that ὑπόμνημα εἰς means a line-by-line commentary, as opposed to ὑπόμνημα followed by the genitive.[33] By Deas' distinction the citation of Suda θ 142, ὑπόμνημα εἰς τὸ Ἀρχιμήδους ἐφοδι<κ>όν, would imply that Theodosius wrote a line-by-line commentary on the *Ephodos*. Such a detailed commentary does offer the opportunity to intervene deep enough into the text that Theodosius could have simply translated the Doric into Koine. Beyond the change in dialect, there is no clear indication that Theodosius' commentary has intruded upon the text of the *Ephodos* in the palimpsest.[34]

I can distinguish at least two stages of transmission by the errors in the manuscript, mostly from dittography. There are errors arising from the translation of Archimedes' Doric into Koine and further errors arising from the transmission of the Koine text. Following are a list of representative mistakes of each kind of transmission.

<u>Scribal errors in the translation from Doric to Koine:</u>

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[30] See OCD[3] *s.v.* Theodosius (4).
[31] Pfeiffer (1968: 213-8, 278).
[32] Harding (2006: 14-19).
[33] Deas (1931: 76-8).
[34] While there are the possible remnants of two Doric aorist forms, εἴπαμεν (Doric would be εἴπαμες), at Netz et al. (2008: 47r2.17, 47r2.19), it is better to see in εἴπαμεν the aorist late Koine form.

113 ΔΕΚΑΠΕΠΕΙϹΜΕΝΟϹ — the leftmost vertical of Π was seen as Ι in dittography and written ΔΕ/ΚΑΙ/ΠΕΠΕΙϹΜΕΝΟϹ

150 ΕΧΟΥϹΑϹΤΟΝ — seen without the final sigma and written ΕΧΟΥϹΑ/ΤΟΝ

234 ΟϹΑΙΚΑΑΧΘΩϹΙΝ — seen with dittography as ΟϹΑΙ/ΑΙ/ΚΑ/ΑΧΘΩϹΙΝ and written ΟϹΑΙ/ΕΑΝ/ΗΧΘΩϹΙΝ

282-3 ΕΙΜΕΝΕΤΑΞΟΜΕϹ — seen as dittography of Ε as ΕΙΜΕΝ/ΤΑΞΟΜΕϹ and written with haplography ΕΙΝΑΙ/ΤΑΞΟΜΕΝ

Scribal errors in the transmission of the Koine:

226 ΙϹΗΗΗΤΘ — seen as dittography of Η and written with haplography ΙϹΗ/Η/ΤΘ

231 ΠΡΟϹΗΤ — written with dittography ΠΡΟϹ/ΤΗΝ/ΗΤ

The palimpsest is written in *scriptio plena* except when the prepositions *κατά* and *ἀπό* precede word-initial vowels (lines 76, 147, 161, and 238) and I have continued this in my reconstruction of the Doric text. I have attempted to reconstruct Doric forms only in accord with Heiberg (1879) and Heiberg (1910-15) and have not consulted any contemporary Syracusan inscriptions or coins for comparison.[35] I have rewritten the following types of words and morphologies into Doric in accord with the forms given by Heiberg: articles, pronouns, prepositions, *εἰ*, *ἄν*, 1st declension endings, 3rd declension genitive singulars, 3rd declension genitive plurals, 3rd declension dative plurals, 3rd declension accusative plurals, forms of *εἰμί*, 3rd person active plurals, 1st person active plurals, subjunctives of athematic verbs, present participles of athematic verbs, present active infinitives of athematic verbs, perfect active infinitives, *-α* in stems and personal endings for Koine *-η* except following liquids (but *ἄλλαλος*, *παραλλαλόγραμμος*, and forms of *λαμβάνω* retain *-α*), 3rd person active futures, futures of stems ending in dentals, and uncontracted forms of contract verbs (except for *ε*+*ε* which remains contracted as *ει*).

Archimedes' Doric forms a bridge to Koine, freely mixing older Doric and contemporary Koine morphologies and including some Koine syntactical constructions, e.g. periphrasis of *εἰμί* and participle standing for the present (*passim*) and the parallelism

[35] Heiberg (1879: 69-94) is the most explicit discussion of Archimedes' Doric dialect.

of finite verb and participle (74-5). There are several forms, both Doric and Koine, which Archimedes seems to have used interchangeably; and in these cases I have retained the Koine forms of the palimpsest in the absence of further manuscript evidence. Heiberg treated both manuscript εἰς and ἐς as Archimedean forms; I have retained the Koine εἰς of the palimpsest throughout. I have retained the ἐστί of the palimpsest throughout and made no attempt to change some forms into ἐντί, a usage of the plural for singular that Archimedes sometimes employs. Moreover, in the absence of more evidence, I have left the ending of all feminine participles (except the aorist passive) as –ουσα; Heiberg treated both manuscript –ουσα and –οισα as Archimedean forms. I differ, however, with Heiberg in one place where he tolerated both Koine and Doric forms: I have changed all forms of ἐάν, εἰ ἄν, and ἤν into the Doric form αἴ κα on the basis of the scribal mistakes of 113 and 234. I have left the title in Koine because, as I argue in chapter 3.1.1, I believe that Archimedes' original title was ΕΦΟΔΟϹ and a later editor, perhaps Theodosius of Byzantium who wrote the commentary (doubtless in Koine) on the *Ephodos* in the 2nd century BCE, added the rest of the manuscript title.

I have made two diagnostic conjectures, the type advocated by West (1973), "that is, a conjecture which, while no one can feel confident that it is right, serves the purpose of indicating the kind of sense that is really required or the kind of corruption that occurred."[36] I intend the following to be diagnostic conjectures:

62B <αι κυλίνδρου, ἕτερον δὲ ἐπιφανεί> — At least one line has dropped out here; I suspect the lacuna was a short one, rather than several lines. The line I substitute is the shortest possible and could have fallen out through homeoteleuton.

282-3 <ἐ>τάξο|μες — Almost everyone is unhappy with the manuscript reading τάξο|μεν.[37] Most scholars have wanted to see a verb of searching and sometimes taken

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[36] West (1973: 58).

[37] Rufini (1961: 111-12n.19) is representative of many scholars when he translates "ne ricercherò la dimonstrazione geometrica" and explains "La parola che nel testo corrisponde al verbo 'ne ricercherò' è il verbo τάξομεν. Reinach dubitò che fosse questa una lezione giusta; ma Heiberg nella 2ª edizione la conferma come esatta, e traduce *suo loco proponemus* (cioè, *a suo luogo ne daremo*) come se Archimede avesse avuto l'intenzione di ripetere, in questa lettera, la dimonstrazione già esposta nell'opuscolo citato. Ora, mi pare difficile sostenere questo; credo invece che con quel verbo egli abbia semplicemente voluto

τάξομεν in this sense; or they have rightly understood the word to mean "arrange" and, after Heiberg-Zeuthen (1907), believed Archimedes listed his previous proofs at the end of the treatise. I suggest a different sense is needed and, with Arendt (1914), believe that the word governs not the geometrical proofs but is a continued statement about the mechanical method. The addition of <ἐ> to the manuscript τάξομεν is a simpler solution paleographically than Arendt's (1914) change back to a present participle.

The left-most numbers are my continuous reference numbers in the apparatus; the numbers under the column number refer to individual lines on that column. Heiberg's (1913) page numbers and notations of the mathematical structure are marked on the right.

I print Heiberg's diagram for *Ephodos* proposition 1 for the reader's benefit, even though it is not a critical edition of the diagram in the palimpsest.

I print at the end a literal translation of the first 16 columns which, following the translation practice of Netz (2004a), aims "to remove all barriers having to do with the foreign language itself, leaving all other barriers intact."[38]

indicare l'opportunità e la necessità di ricercare una dimonstrazione geometrica. Con la traduzione che ho preferito credo di non essermi allontanato letterale e insieme di aver superato l'accennata difficoltà."

[38] Netz (2004a: 3).

de apparatu critico

Libris usus sum his:

Arendt = Arendt (1914)

Heiberg = Heiberg (1913)

Netz = Netz et al. (2008)

Reinach = Reinach *apud* Heiberg (1913)

Sigla varia indicavi haec:

[ ] *textum exclusendum*

. *textum dubium*

< > *textum supplemendum*

{ } *litterae nequent legi*

/ *paragraphum novum praeeunte* Heiberg

| *lineam novam in columna*

46r col. 2

ΑΡΧΙΜΗΔΟΥϹ ΠΕΡΙ ΤΩΝ ΜΗ- 426
ΧΑΝΙΚΩΝ ΘΕΩΡΗΜΑΤΩΝ ΠΡΟϹ
ΕΡΑΤΟϹΘΕΝΗΝ. ΕΦΟΔΟϹ
Ἀρχιμήδης Ἐρατοσθένει εὖ πρά-
ττειν. / ἀπέστειλά τοι πρότερον
τῶν εὑρημένων θεωρημάτων
ἀναγράψας αὐτὰς τὰς προτά-
σιες φάμενος εὑρίσκειν ταύτας
τὰς ἀποδείξιας, ἃς οὐκ εἶπα
ἐπὶ τοῦ παρέοντος· ἦσαν δὲ τῶν ἀ-
πεσταλμένων θεωρημάτων
αἱ προτάσεις αἵδε· τοῦ μὲν
πρώτου· αἵ κα εἰς πρίσμα ὀρθὸν πα-
ραλλαλόγραμμον ἔχον βάσιν
κύλινδρος ἐγγραφῆι τὰς μὲν
βάσιες ἔχων ἐν τοῖς ἀπεναν-
τίον παραλλαλογράμμοις, τὰς
δὲ πλευρὰς ἐπὶ τῶν λοιπῶν τε̣σ̣-
σάρων ἐπιπέδων ἐφαπτομέ-

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3 ΕΡΑΤΟΣΘΕΝΗΝ. ΕΦΟΔΟΣ Netz *apud quem autem punctum in tituli fine certe intelligendum* : Ἐρατοσθένην ἔφοδος. Heiberg *apud quem deficit punctum inter verba* || 5 τοι *dorice scripsi* : σοι C || 7 αὐτὰς Netz : αὐτῶν Heiberg || 7-8 προτά|σιες *dorice scripsi* : προτά|σεις C || 9 ἀποδείξιας *dorice scripsi* : ἀποδείξεις C εἶπα *scripsi cf. Archimedis Arenarius* 216.21 εἴπαμες : εἶπον C || 10 παρέοντος *dorice scripsi* : παρόντος C || 12-13 τοῦ μὲν | πρώτου Heiberg : τοῦ μὲν | $\overline{\text{Α}}$ πρώτου Netz || 13 αἵ κα *dorice scripsi* : ἐὰν C || 13-14 πα|ραλλαλόγραμμον *dorice scripsi, et scribendum aut certe intellegendum* τετράγωνον *dixit* Heiberg *cf. linea* 23 : πα|ραλληλόγραμμον C || 16 βάσιες *dorice scripsi* : βάσεις C || 17 πα|ραλλαλόγραμμον *dorice scripsi* : πα|ραλληλόγραμμον C || 18-19 τε̣σ̣|σάρων Netz : τ̣ο̣ῦ̣ | π̣ρ̣ι̣σ̣μ̣α̣τ̣ο̣ς̣ Heiberg || 19 ἐφαπτομέ- Netz : κ̣α̣ὶ̣ δ̣ι̣ὰ̣ τ̣ε Heiberg

43v col. 2

νας, διὰ δὲ τοῦ κέντρου τοῦ κύκλου,
ὅς ἐστι βάσις τοῦ κυλίνδρου, καὶ μι-
ᾶς πλευρᾶς τοῦ τετραγώνου τοῦ
ἐν τῶι κατεναντίον ἐπιπέδωι
ἀχθῆι ἐπίπεδον, τὸ ἀχθὲν ἐπί-
πεδον ἀποτεμεῖ τμᾶμα ἀπὸ
τοῦ κυλίνδρου, ὅ ἐστι περιεχόμε-
νον ὑπὸ δύο ἐπιπέδων καὶ ἐπι-
φανείας κυλίνδρου, ἑνὸς μὲν
τοῦ ἀχθέντος, ἑτέρου δὲ ἐν ὧι ἀ
βάσις ἐστὶν τοῦ κυλίνδρου, τᾶς <δὲ> με-
ταξὺ τῶν εἰρημένων ἐπιπέ-
δων, <ὥστε> τὸ ἀποτμαθὲν ἀπὸ τοῦ
κυλίνδρου τμᾶμα ἕκτον μέρος
ἐστὶ τοῦ ὅλου πρίσματος.
τοῦ δὲ ἑτέρου θεωρήματος ἁ πρότασις
ἅδε ὅτι αἵ κα εἰς κύβον κύλινδρος

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20 *lineae nihil legit* Heiberg || 21 *ὅς corr.* Heiberg : ὅ C || 25 *ἀποτεμεῖ corr.* Heiberg : *ἀποτέμη* Netz : *ἀποτεμῆ* Heiberg *τμᾶμα dorice scripsi* : *τμῆμα* C || 29 *ἁ dorice scripsi* : *ἡ* C || 30 *τᾶς dorice scripsi* : *τῆς* C <δὲ> *scripsi* : <δὲ *ἐπιφανείας τῆς*> *suppl.* Heiberg || 32 <*ὥστε*> *addidi* : <δὲ> *ante ἀποτμηθὲν suppl.* Heiberg *ἀποτμαθὲν dorice scripsi* : *ἀποτμηθὲν* C || 33 *τμᾶμα dorice scripsi* : *τμῆμα* C || 35 *τοῦ δὲ ἑτέρου* Heiberg : $\overline{\text{B}}$ *τοῦ δὲ ἑτέρου* Netz || 35-6 *ἡ πρότασις* | *ἥδε ὅτι ἐὰν* Netz, *a me dorice rescriptum* : *ἡ πρότα̣σ̣|ις̣ ἥδε· ἐὰν* Heiberg

46v col. 1

ἐγγραφῆι τὰς μὲν βάσιες ἔχων
ποτὶ τοῖς κατεναντίον παραλλα-
λογράμμοις, τὰν δὲ ἐπιφάνειαν
τῶν λοιπῶν τεσσάρων ἐπιπέ-
δων ἐφαπτόμενος, ἐγγραφῆι <δὲ> καὶ 428
ἄλλος κύλινδρος εἰς τὸν αὐτὸν κύ-
βον τὰς μὲν βάσιες ἔχων ἐν ἄλλοις
παραλληλογράμμοις, τᾶι δὲ ἐπι-
φανείαι τῶν λοιπῶν τεσσάρων
ἐπιπέδων ἐφαπτόμενος, τὸ πε-
ριλαφθὲν σχῆμα ὑπὸ τᾶν ἐπι-
φανειᾶν τῶν κυλίνδρων, ὅ ἐστιν
ἐν ἀμφοτέροις τοῖς κυλίνδροις,
δίμοιρόν ἐστι τοῦ ὅλου κύβου. / συμ-
βαίνει δὲ ταῦτα τὰ θεωρήματα
διαφέρειν τῶν πρότερον εὑρη-
μένων· ἐκεῖνα μὲν γὰρ τὰ σχή-
ματα τά τε κωνοειδέα καὶ
σφαιροειδέα καὶ τὰ τμάματα,

37 *βάσιες dorice scripsi* : *βάσεις* C || 38 *ποτὶ dorice scripsi* : *πρὸς* C || 38-9 *παραλλα|λογράμμοις dorice scripsi* : *παραλλη|λογράμμοις* C || 39 *τὰν dorice scripsi* : *τὴν* C || 41 *ἐφαπτόμενος* Netz, *approbante* Reinach : *ἐφαπτομένην* Heiberg <δὲ> *addidi* || 43 *βάσιες dorice scripsi* : *βάσεις* C || 44 *παραλλαλογράμμοις dorice scripsi* : *παραλληλογράμμοις* C || 44-5 *τῆι δὲ ἐπι|φανείαι* Netz, *a me dorice rescriptum* : *τὴν δὲ ἐπι|φανείαν* Heiberg || 46 *ἐφαπτόμενος* C : *ἐφαπτομένην scr.* Heiberg || 46–7 *περι|λαφθὲν dorice scripsi* : *περι|ληφθὲν* C || 47 *τᾶν dorice scripsi* : *τῶν* C || 47-8 *ἐπι|φανειᾶν dorice scripsi* : *ἐπι|φανειῶν* C || 54 *κωνοειδέα dorice scripsi* : *κωνοειδῆ* C || 55 *σφαιροειδέα dorice scripsi* : *σφαιροειδῆ* C *τμάματα dorice scripsi* : *τμήματα* C

43r col. 1

56 1 τὰ αὐτά τε ποτὶ ἄλλαλα καὶ ποτὶ
2 κώνων καὶ κυλίνδρων συνε-
3 κρίναμες, ἐπιπέδοις δὲ περι-
4 εχομένωι στερεῶι σχήματι οὐ-
60 5 δὲν αὐτῶν ἴσον ἐὸν εὕρηται,
6 τούτων δὲ τῶν σχημάτων τὸ μὲν <περιεχόμενον>
62A 7 δυσὶν ἐπιπέδοις καὶ ἐπιφανεί-
62B <αι κυλίνδρου, ἕτερον δὲ ἐπιφανεί>-
8 αις κυλίνδρων, ἑκάτερον αὐτῶν
9 ἐπιπέδοις περιεχομένωι στερε-
65 10 ῶι σχήματι ἴσον εὑρίσκεται.
11 τούτων δὴ τῶν θεωρημάτων
12 τὰς ἀποδείξιας ἐν τῶιδε τῶι βι-
13 βλίωι γράψας ἀποστέλλω τοι. /
14 ὁρῶν δέ τυ, καθάπερ λέγω, σπου-
70 15 δαῖον καὶ φιλοσοφίας προεστᾶ-
16 τα ἀξιολόγως καὶ τὰν ἐν τοῖς
17 μαθημάτεσσιν κατὰ τὸ ὑποπίπτον

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56 *lineae nihil legit* Heiberg ποτὶ ἄλλαλα … ποτὶ *dorice scripsi* : πρὸς ἄλληλα … πρὸς C || 57-8 συνε|κρίναμες *dorice scripsi* : συνε|κρίναμεν C || 58 ἐπιπέδοις *corr.* Heiberg : ἐπιπέδων C || 61 τὸ μὲν Netz : τῶν Heiberg <περιεχόμενον> *addidi quod, etsi non scriptum esset, certe intelligendum* || 62B *lineam novam inservi et* <αι κυλίνδρου, ἕτερον δὲ ἐπιφανεί> *addidi* || 63 ἑκάτερον *scr.* Heiberg : ἕκαστον C αὐτῶν Netz : ἐνὶ τῶν Heiberg || 64-5 ἐπιπέδοις περιεχομένωι στερε|ῶι σχήματι *scripsi* : ἐπιπέδωι περιεχομένωι στερε|ῶι σχήματι Netz : ἐπιπέδοις περιεχομένων στερ|εῶν σχημάτων *scr.* Heiberg : ἐπιπέδωι περιεχομένωι στερ|εῶι σχήματι Heiberg || 67 ἀποδείξιας *dorice scripsi* : ἀποδείξεις C || 68 ἀποστέλλω *scripsi*, Heiberg *dicente praesens fortasse scribendum ac non excudente hoc* : ἀποστελῶ C τοι *dorice scripsi* : σοι C || 69 τυ *dorice scripsi* : σε C || 70 προεστᾶ|τα *dorice scripsi* : προεστῶ|τα C || 71 τὰν *dorice scripsi* : τὴν C || 72 μαθημάτεσσιν *dorice scripsi* : μαθήμασιν C

46v col. 2

θεωρίαν τετιμηκότα ἐδοκίμα-
σα γράψαι τοι καὶ εἰς τὸ αὐτὸ βιβλί-
ον ἐφοδιάσας τρόπου τινὸς ἰδιό-
τητα, καθ' ὅν ἐπιπορευομένωι
ἐσσεῖται λαμβάνειν ἀφορμὰς εἰς
τὸ δύνασθαί τινα τῶν ἐν τοῖς
μαθημάτεσσιν θεωρεῖν διὰ τῶν
μηχανικῶν. τοῦτο δὲ πέπ<ε>ισμαι χρή-
σιμον εἶμεν οὐδὲν ἧσσον <ἢ> καὶ εἰς τὰν
ἀπόδειξιν αὐτῶν τῶν θεωρη-
μάτων. καὶ γὰρ <τινα τῶν> πρότερον μοι φα-
νέντων μηχανικῶς ὕστερον γε-
ωμετρικῶς ἀπεδείχθη διὰ τὸ
χωρὶς ἀποδείξιος εἶμεν τὰν διὰ τοῦ
τρόπου θεωρίαν· ἑτοιμότερον γάρ
ἐστι προλαβόντι διὰ τοῦ τρόπου γνῶ-
σίν τινα τῶν ζητημάτων πο-
ρίσασθαι τὰν ἀπόδειξιν μᾶλλον
ἢ μηδενὸς ἐγνωσμένου ζητεῖν. 430

74 τοι *dorice scripsi* : σοι C || 75 ἐφοδιάσας *scripsi* : ἐξορίσας Netz : ἐξορίσαι Heiberg || 76 ἐπιπορευομένωι *scripsi* : ἐπιπορευόμενον Netz : σοι παρεχόμενον Heiberg || 77 ἐσσεῖται *dorice scripsi* : ἔσται C || 79 μαθημάτεσσιν *dorice scripsi* : μαθήμασιν C || 80 πέπ<ε>ισμαι *corr.* Heiberg : πέπισμαι C || 81 εἶμεν *dorice scripsi* : εἶναι C <ἢ> *addidi, minime vero intelligenda genetiva* αὐτῶν τῶν θεωρη|μάτων *cum comparativo* ἧσσον τὰν *dorice scripsi* : τὴν C || 83 γὰρ <τινα τῶν> πρότερον *scr.* Heiberg : γὰρ προτέρων C || 86 ἀποδείξιος εἶμεν τὰν *dorice scripsi* : ἀποδείξεως εἶναι τὴν C || 86-7 τοῦ | τρόπου C : τούτου τοῦ | τρόπου *scr.* Reinach || 88 προλαβόντι *scripsi* : προλαβόντα C || 89 τινα C, *dubito enim an* τινα *lateat pronomium doricum, ut* τιν *pro vulgare* σε *in exemplari dorice scripto* προλαβόντα … τιν ζητημάτων C, *necsio an Archimedes hoc verbum scripserit more Doriensium antiquiorum, ut* ζατημάτων || 90 τὰν *dorice scripsi* : τὴν C || 91 ζητεῖν C, *necsio an Archimedes hoc verbum scripserit more Doriensium antiquiorum, ut* ζατεῖν

43r col. 2

διὸ καὶ τὰς εὑρήσιες τῶν θεωρη-
μάτων τῶνδε <ὧν> Εὔδοξος ἐξήνεγ-
κε πρῶτος τὰν ἀπόδειξίν
τε τοῦ κώνου καὶ τᾶς πυραμίδος,
ὅτι τρίτον μέρος ἐστὶν ὁ μὲν κῶνος
τοῦ κυλίνδρου, ἁ δὲ πυραμὶς τοῦ
πρίσματος, τῶν βάσιν ἐχόν-
των τὰν αὐτὰν καὶ ὕψος ἴσον, οὐ
μικρὰν ἀπονείμαι <κα> τις Δημο-
κρίτωι μερίδα πρώτωι τὰν ἀ-
πόφασιν τὰν περὶ τοῦ εἰρημέ-
νου σχήματος χωρὶς ἀποδείξι-
ος ἀποφαναμένωι. ἁμῖν δὲ
συμβαίνει καὶ τοῦ νῦν ἐκδιδο-
μένου θεωρήματος τὰν εὕρεσιν
ὁμοίαν ταῖς πρότερον γεγενῆσθαι·
ἠβουλήθην δὲ τὸν τρόπον ἀνα-
γράψας ἐξενεγκεῖν ἅμα μὲν

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92 *lineae nihil legit* Heiberg εὑρήσιες *dorice scripsi* : εὑρήσεις C || 93 τῶνδε *scripsi* : τούτων C <ὧν> *ad.* Heiberg || 93-4 ἐξήνεγ|κε Netz : ἐξηύρη|κεν Heiberg || 94 τὰν *dorice scripsi* : τὴν C || 95 τε Netz : περὶ *ex* .ε. τοῦ *suppl.* Heiberg τᾶς *dorice scripsi* : τῆς C || 97 ἁ *dorice scripsi* : ἡ C || 99 τὰν αὐτὰν *dorice scripsi* : τὴν αὐτὴν C || 100 <ἄν> *suppl.* Heiberg, *a me dorice rescriptum* || 101 τὰν *dorice scripsi* : τὴν C || 102 τὰν *dorice scripsi* : τὴν C || 102-3 τοῦ εἰρημέ|νου σχήματος C : τῶν εἰρημένων σχημάτων *exeuntia pluralia fortasse scribenda supposuit* Heiberg || 103-4 ἀποδείξι|ος *dorice scripsi* : ἀποδείξε|ως C || 104 ἀποφαναμένωι ἁμῖν *dorice scripsi* : ἀποφηναμένωι ἡμῖν C || 105-6 τοῦ νῦν ἐκδιδο|μένου θεωρήματος C : τῶν ἐκδιδο|μένων θεωρημάτων *exeuntia pluralia fortasse scribenda supposuit* Heiberg || 106 τὰν *dorice scripsi* : τὴν C

57r col. 1

καὶ διὰ τὸ προειρηκέμεν ὑπὲρ
αὐτοῦ, μή τισιν δοκέωμες κ̣ενὰν
φ̣ω̣νὰν καταβεβλῆ̣σθαι, ἄμα
δ̣έ̣ κα πεπει̣σμένο[ι]ς εἰς τὸ μάθη-
μα οὐ μικρὰν συμβαλέσθαι χρεί-
αν· ὑπολαμβάνω γάρ τινας ἢ
τῶν ἐόντων ἢ ἐπιγ[ε]ινομένων διὰ
τοῦ ἀποδειχθέντος τρόπου καὶ
ἄλλα θεωρήματα οὔ̣πω {. .} ὑ-
ποπεπτωκό<τ>α εὑρήσειν. / γρά-
φομες οὖν πρῶτον τὸ καὶ πρῶ-
τον φ̣ανὲν διὰ τῶν μηχανικῶν,
ὅτι πᾶν τμᾶμα ὀρθογωνίου κώ-
νου τομᾶς ἐπίτριτόν ἐστιν τρι-
γώνου τοῦ βάσιν ἔχοντος τὰν
αὐτὰν καὶ ὕψος ἴσον, μετὰ δὲ τοῦ-
το ἕκαστον <τῶν> διὰ τοῦ αὐτοῦ τρόπου
θεωρηθέντων· ἐπὶ τέλει δ̣ὲ̣ τοῦ βι-
βλίου γράφομες τὰς γεωμ<ετρ>ο̣<υ>-
{<μένας> }
{ <προ>-}

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110 *προειρηκέμεν dorice scripsi* : προειρηκέναι C || 111-2 δοκέωμες κ̣ενὰν | φ̣ω̣νὰν *dorice scripsi* : δοκῶμεν κ̣ενὴν | φ̣ω̣νὴν C || 113 κα *scripsi* : κ̣αὶ C πεπει̣σμένο[ι]ς *corr.* Heiberg || 114 <ἄν> *ante* συμβαλέσθαι *suppl.* Heiberg || 115-6 *inter* ἢ *et* τῶν *signum* | *deficit* Heiberg *opinor errore typographico* || 116 ἐόντων *dorice scripsi* : ὄντων C ἐπιγ[ε]ινομένων *corr.* Heiberg || 118-119 ο<ὔ>πω {. .} ὑ|ποπεπτωκό<τ>α Netz : ο̣ὔ̣πω̣ ἡμῖν σ̣υ̣ν̣|πα̣ρα̣πεπτωκότα Heiberg || 119-20 γρά|φομες *dorice scripsi* : γρά|φομεν C || 122 τμᾶμα *dorice scripsi* : τμῆμα C || 123 τομᾶς *dorice scripsi* : τομῆς C || 124-5 τὰν | αὐτὰν *dorice scripsi* : τὴν | αὐτὴν C || 126 <τῶν> *suppl.* Heiberg || 128 γράφομες *dorice scripsi* : γράφομεν C || 128-9 γεωμ<ετρ>ο̣<υ|μένας> Netz, *quam formam non dorice conversi ut iam palimpsesti lectio intelligeatur* : τὰς γεωμετρι̣|<κὰς> Heiberg || 129 <κὰς ἀποδείξεις ἐκείνων τῶν> *suppl.* Reinach || 130 <προ> *scripsi* : <θεωρημάτων ὧν τὰς προ> *suppl.* Reinach

64v col. 1

τάσιες ἀπεστείλαμέν<. εὐτύχει.> /
αἴ κα ἀπὸ μεγέθεος μέγεθος ἀ- post. 1
φαιρεθῆι, <τὸ δὲ αὐτὸ σαμεῖον κέν>-
τρον τοῦ βάρεος <ᾗι τοῦ τε ὅλου>
καὶ τοῦ ἀφαιρεομένου, <τοῦ> 432
λοιποῦ τὸ αὐτὸ σαμεῖον <κέντρον>
ἐστὶ τοῦ βάρεος. / <αἴ κα ἀπὸ μεγέ>- post. 2
θεος μέγεθο<ς> ἀφαιρ<ε>θ<ῆι, ᾗι δὲ>
μὴ τὸ αὐτὸ σαμεῖον κέντρον
τοῦ βάρεος τοῦ τε ὅλου μεγέθεος
καὶ τοῦ ἀφαιρεομένου μεγέθεος,
τὸ κέντρον ἐστὶ τοῦ βάρεος τοῦ
λοιποῦ μεγέθεος ἐπὶ τᾶς <εὐθείας>
τᾶς ἐπιζευγνυούσας τὰ κέντρα
τοῦ βάρεος τοῦ τε ὅλου μεγέ<θεος>
<καὶ τοῦ ἀφαιρεομέ>νου ἐκβεβλη-

131-146 *columnam omnem vix legere potuit* Netz || 131 τάσιες *dorice scripsi* : τάσεις Heiberg <. εὐτύχει.> *addidi* : <σοι πρότερον.> *suppl.* Reinach *qui similia lineis* 5-8 *scripsit* || 131-2 ΠΡΟΛΑΜΒΑΝΟΜΕΝΑ *in linea nova inter has lineas scr.* Heiberg || 132 αἴ κα … μεγέθεος *dorice scripsi* : ἐὰν … μεγέθους Heiberg || 133 <τὸ δὲ αὐτὸ σημεῖον κέν> *suppl.* Heiberg, *a me dorice rescriptum* || 134 βάρεος *dorice scripsi* : βάρους Heiberg <ᾗι τοῦ τε ὅλου> *suppl.* Heiberg || 135 ἀφαιρεομένου *dorice scripsi* : ἀφαιρουμένου C <τοῦ> *suppl.* Heiberg || 136 σαμεῖον *dorice scripsi* : σημεῖον Heiberg <κέντρον> *suppl.* Heiberg || 137 βάρεος *dorice scripsi* : βάρους Heiberg <ἐὰν ἀπὸ μεγέ> *suppl.* Heiberg, *a me dorice rescriptum* || 137-8 <μεγέ>|θεος *dorice scripsi* : <μεγέ>|θους C || 138 <ῆι, ᾗι δὲ> *suppl.* Heiberg || 139 σαμεῖον *dorice scripsi* : σημεῖον Heiberg || 140 βάρεος *dorice scripsi* : βάρους C μεγέθεος *dorice scripsi* : μεγέθους C ||141 ἀφαιρεομένου μεγέθεος *dorice scripsi* : ἀφαιρουμένου μεγέθους C || 142 βάρεος *dorice scripsi* : βάρους C || 143 μεγέθεος … τᾶς *dorice scripsi* : μεγέθους … τῆς C <εὐθείας> *suppl.* Heiberg || 144 τᾶς ἐπιζευγνυούσας *dorice scripsi* : τῆς ἐπιζευγνούσης C || 145 βάρεος *dorice scripsi* : βάρους Heiberg μεγέ<θους> Netz, *a me dorice rescriptum* : <καὶ> Heiberg || 146 <καὶ τοῦ ἀφαιρουμέ> *suppl.* Netz, *a me dorice rescriptum* : <τοῦ ἀφαιρουμέ> *suppl.* Heiberg

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μένας καί <τινος> ἀφαιρεθείσας ἀπ' αὐ-
τᾶς ποτί <τε> τὰν μεταξὺ τῶν εἰρημέ-
νων κέντρων τοῦ βάρεος τοῦτον
ἐχούσας τὸν λόγον, ὃν ἔχει τὸ βάρος
τοῦ ἀφα<ι>ρεμένου μεγέθεος ποτὶ
τὸ [λοιπὸν] βάρος τοῦ λοιποῦ μεγέθεος. /
αἴ κα ὁποσωνοῦν μεγεθέων τὸ κέν- post. 3
τρον τοῦ βάρεος ἐπὶ τᾶς αὐτᾶς
εὐθείας ᾖ<ι>, καὶ τοῦ ἐκ πάντων συγ-
κειμένου μεγέθεος τὸ κέντρον ἐσσεῖται
ἐπὶ τᾶς αὐτᾶς εὐθείας. / πάσας post. 4
εὐθείας τὸ κέντρον ἐστὶ τοῦ βάρεος
ἃ διχοτομία τᾶς εὐθείας. / παντὸς post. 5
τριγώνου τὸ κέντρον ἐστὶν τοῦ βά-
ρεος τὸ σαμεῖον, καθ' ὃ αἱ ἐκ τᾶν
γωνιᾶν τοῦ τριγώνου ἐπὶ μέσας
τᾶς πλευρὰς ἀγόμεναι εὐθεῖαι
τέμνοντιν ἀλλάλας. / παντὸς πα- post. 6
ραλλαλογράμμου τὸ κέντρον ἐστὶν
<τοῦ βάρεος τὸ σαμεῖον, καθ' ὃ αἱ>
<διάμετροι συμπίπτοντιν. / κύκλου> post. 7

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147 *μένας dorice scripsi* : *μένης* C *<τινος> addidi* *ἀφαιρεθείσας dorice scripsi* : *ἀφαιρεθείσης* C ‖ 148 *τᾶς ποτί dorice scripsi* : *τῆς πρός* C *<τε> addidi* *τὰν dorice scripsi* : *τὴν* C ‖ 149 *βάρεος dorice scripsi* : *βάρους* C ‖ 150 *ἐχούσης corr.* Heiberg, *a me dorice rescriptum* : *ἔχουσα* C ‖ 151 *ἀφα<ι>ρεμένου μεγέθεος ποτὶ dorice scripsi* : *ἀφη<ι>ρημένου μεγέθους πρὸς* C ‖ 152 [λοιπὸν] *sec.* Heiberg *μεγέθεος dorice scripsi* : *μεγέθους* C ‖ 153 *αἴ κα dorice scripsi* : *ἐὰν* C *ὁποσωνοῦν* Heiberg: *ὁπωσωνοῦν* Netz ‖ 154 *βάρεος … τᾶς αὐτᾶς dorice scripsi* : *βάρους … τῆς αὐτῆς* C ‖ 156 *μεγέθεος … ἐσσεῖται dorice scripsi* : *μεγέθους … ἔσται* C ‖ 157 *τᾶς αὐτᾶς … πάσας dorice scripsi* : *τῆς αὐτῆς … πάσης* C ‖ 158 *βάρεος dorice scripsi* : *βάρους* C ‖ 159 *ἃ … τᾶς dorice scripsi* : *ἡ … τῆς* C ‖ 161 *ρεος τὸ σαμεῖον … τᾶν dorice scripsi* : *ρους τὸ σημεῖον … τῶν* C ‖ 162 *γωνιᾶν dorice scripsi* : *γωνιῶν* C ‖ 163 *τᾶς dorice scripsi* : *τῆς* C ‖ 164 *τέμνοντιν ἀλλάλας dorice scripsi* : *τέμνουσιν ἀλλήλας* C ‖ 165

ραλλαλογράμμου *dorice scripsi* : ραλληλογράμμου C || 166-7 *ex Archimedis De Plan. Aequil.* 142.21-22 *verbatim suppl.* Heiberg || 167 <κύκλου> *suppl.* Heiberg

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168	1	τὸ κέντρον τοῦ βάρεος ἐστὶν ὃ καὶ	
	2	<τοῦ κύκλου> ἐστὶ κέντρον. / παντὸς	post. 8
170	3	κυλίνδρου τὸ κέντρον τοῦ βάρεος	
	4	ἐστὶν ἁ διχοτομία τοῦ ἄξονος. / παν-	post. 9
	5	τὸς πρισματος τὸ κέντρον ἐστὶ τοῦ	
	6	βάρεος ἁ διχοτομία τοῦ ἄξονος. / παν-	post. 10
	7	τὸς κώνου τὸ κέντρον ἐστὶν τοῦ βά-	
175	8	ρεος ἐπὶ τοῦ ἄξονος διαιρεθέντος	434
	9	οὕτως, ὥστε τὸ ποτὶ ταῖ κορυφαῖ τμᾶ-	
	10	μα τριπλάσιον εἶμεν τοῦ λοιποῦ. / χρη-	post. 11
	11	σόμεθα δὲ καὶ [ἐν <τῶι> προγεγραμ-	
	12	μένωι κωνοειδῶν] τῶιδε τῶι θεωρή-	
180	13	ματι· αἴ κα ὁποσαοῦν μεγέθεα ἄλ-	
	14	λοις μεγέθεσιν ἴσα τὸ πλῆθος	
	15	κατὰ δύο τὸν αὐτὸν ἔχη<ι> λόγον τὰ ὁ-	
	16	μοίως τεταγμενα, ἦ<ι> δὲ τὰ πρῶτα	

168 *βάρεος dorice scripsi* : *βάρους* C || 169 <*τοῦ κύκλου*> *suppl.* Heiberg || 170-183 *nihil e lineis legit* Netz || 170 *βάρεος dorice scripsi* : *βάρους* Heiberg || 171 *ἁ dorice scripsi* : *ἡ* Heiberg || 173 *βάρεος ἁ dorice scripsi* : *βάρους ἡ* Heiberg || 175 *ρεος dorice scripsi* : *ρους* Heiberg || 176 *ποτὶ ταῖ κορυφαῖ τμᾶ dorice scripsi* : *πρὸς τῆι κορυφῆι τμῆ* Heiberg || 177 *εἶμεν dorice scripsi* : *εἶναι* Heiberg || 178 <*τῶι*> *suppl.* Heiberg || 178-9 [*ἐν* <*τῶι*> *προγεγραμ*|*μένωι κωνοειδῶν*] *sec.* Heiberg, *supposuit enim haec verba e margine irrepsisse* || 180 *αἴ κα dorice scripsi* : *ἐὰν* Heiberg *μεγέθεα dorice scripsi* : *μεγέθη* Heiberg || 181 *ἴσα* Heiberg : *ἴσοις scr.* Heiberg

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μεγέθεα <ποτὶ ἄλλα μεγέθεα> ἐν λόγοις ὁποιοισοῦν, ἢ τὰ
πάντα ἤ τινα αὐτῶν, καὶ τὰ ὕστε-
ρα μεγέθεα ποτὶ τὰ ὁμόλογα ἐν
τοῖς αὐτοῖς λόγοις ἦ<ι>, πάντα τὰ
πρῶτα μεγέθεα ποτὶ πάντα τὰ
λεγόμενα τὸν αὐτὸν ἔξει λόγον,
ὃν ἔχει πάντα τὰ ὕστερον ποτὶ
πάντα τὰ λεγόμενα. / ἔστω prop. 1
τμᾶμα τὸ ΑΒΓ περιεχόμενον
ὑπὸ εὐθείας τᾶς ΑΓ καὶ ὀρθο-
γωνίου κώνου τομᾶς τᾶς ΑΒΓ,
καὶ τετμάσθω δίχα ἁ ΑΓ κατὰ τὸ Δ,
καὶ παρὰ τὰν διάμετρον ἄχθω ἁ
ΔΒΕ, καὶ ἐπεζεύχθωσαν αἱ ΑΒ
ΒΓ. / λέγω ὅτι ἐπίτριτόν ἐστιν τὸ ΑΒΓ
τμᾶμα τοῦ ΑΒΓ τριγώνου. / ἄχθω-
σαν ἀπὸ τῶν Α Γ σαμείων ἁ μὲν
ΑΖ παρὰ τὰν ΔΒΕ, ἁ δὲ ΓΖ ἐπιψαύ-
ουσα τᾶς τομᾶς, καὶ ἐκβεβλήσ-
<θω> ἁ <ΓΒ καί τετμάσθω τὰν ΑΖ>

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184 μεγέθεα *dorice scripsi* : μεγέθη C <πρὸς ἄλλα μεγέθη> *suppl.* Heiberg, *a me dorice rescriptum*
λόγοις *corr.* Heiberg : τόποις C || 186 μεγέθεα ποτὶ *dorice scripsi* : μεγέθη πρὸς C || 188 μεγέθεα ποτὶ *dorice scripsi* : μεγέθη πρὸς C || 190 ποτὶ *dorice scripsi* : πρὸς C || 191 α′. *in linea nova ante* ἔστω *scr.* Heiberg || 192 τμᾶμα *dorice scripsi* : τμῆμα C || 193 τᾶς *dorice scripsi* : τῆς C || 194 τομᾶς τᾶς *dorice scripsi* : τομῆς τῆς C || 195 τετμάσθω … ἁ *dorice scripsi* : τετμήσθω … ἡ C || 195 κατὰ τὸ Δ Netz : τῶι Δ Heiberg || 196 τὰν … ἄχθω ἁ *dorice scripsi* : τὴν … ἤχθω ἡ C || 199 τμᾶμα *dorice scripsi* : τμῆμα C || 199-200 ἄχθω|σαν *dorice scripsi* : ἤχθω|σαν C || 200 σαμείων ἁ *dorice scripsi* : σημείων ἡ C || 201 τὰν … ἁ *dorice scripsi* : τὴν … ἡ C || 202 τᾶς τομᾶς *dorice scripsi* : τῆς τομῆς C || 203 <θω> ἡ <ΓΒ καί τετμήσθω τὴν ΑΖ> *scr.* Netz, *a me dorice rescriptum* : *lineam in hoc loco non recognovit* Heiberg

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<=κα>τὰ τὸ Κ, καὶ <κ>εί<σθω τῶι ΓΚ> ἴσα
ἁ ΚΘ, καὶ νοείσθω ζυγὸς ὁ ΓΘ καὶ
μέσον αὐτοῦ τὸ Κ καὶ τῶι ΕΔ πα-
ράλλαλος τυχοῦσα ἁ ΜΞ. / ἐπεὶ οὖν
παραβολή ἐστιν ἁ ΓΒΑ, καὶ ἐφά-
πτεσθαι ἁ ΓΕ, καὶ τεταγμένως ἁ
ΓΔ, ἴσα ἐστὶν ἁ ΕΒ τῶι ΒΔ· τοῦτο γὰρ ἐν
τοῖς στοιχείοις δείκνυται· διὰ δὴ
τοῦτο, καὶ διότι παράλλαλοί εἰσιν
αἱ ΖΑ ΜΞ τῶι ΕΔ, ἴσα ἐστὶν καὶ ἁ
μὲν ΜΝ τῶι ΝΞ, ἁ δὲ ΖΚ τῶι ΚΑ.
καὶ ἐπεί ἐστιν ὡς ἁ ΓΑ ποτὶ ΑΞ, οὕ-
τως ἁ ΜΞ ποτὶ ΞΟ, [τοῦτο γὰρ τὸ
λῆμμα δείκνυται,] ὡς δὲ ἁ ΓΑ ποτὶ
ΑΞ, οὕτως ἁ ΓΚ ποτὶ ΚΝ, καὶ ἴσα
ἐστὶν ἁ ΓΚ τῶι ΚΘ, ὡς ἄρα ἁ ΘΚ
ποτὶ ΚΝ, οὕτως ἁ ΜΞ ποτὶ ΞΟ.

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204 <κα>τὰ τὸ Κ, καὶ <κ>εί<σθω τῆι ΓΚ> ἴση Netz, *a me dorice rescriptum* : <θω ἡ ΓΒ ἐπὶ τὸ Κ, καὶ κείσθω τῆι ΓΚ> *post lineam* 202 *scr.* Heiberg || 205 ἡ ΚΘ Netz, *a me dorice rescriptum* : <ἴση ἡ ΚΘ> *scr.* Heiberg || 206 τῆι ΕΔ Heiberg, *a me dorice rescriptum* : τὸ ΕΔ Netz || 207 ράλλαλος … ἁ *dorice scripsi* : ράλληλος … ἡ C || 208 παραβολή *interpolationem notavit* Heiberg, *Archimedes enim scripserat* ὀρθογωνίου κώνου τομά ἁ *dorice scripsi* : ἡ C || 208-9 ἐφά|πτεσθαι Netz : ἐφά|πτεται Heiberg || 209 ἁ *dorice scripsi* : ἡ C ΓΕ Netz : ΓΖ Heiberg ἁ *dorice scripsi* : ἡ C || 210 ἴσα … ἁ … τῶι *dorice scripsi* : ἴση … ἡ … τῆι C || 212 παράλλαλοί *dorice scripsi* : παράλληλοί C || 213 τῶι … ἴσα … ἁ *dorice scripsi* : τῆι … ἴση … ἡ C || 214 τῶι … ἁ … τῶι *dorice scripsi* : τῆι … ἡ … τῆι C || 215 ἁ *dorice scripsi* : ἡ C ΓΑ *corr.* Heiberg : ΓΔ C ποτὶ *dorice scripsi* : πρὸς C || 216 ἁ … ποτὶ *dorice scripsi* : ἡ … πρὸς C ΞΟ *corr.* Heiberg : ΞΘ C || 216-7 [τοῦτο γὰρ τὸ | λῆμμα δείκνυται,] *praeeunte* Heiberg *seclusi* : τοῦτο γὰρ τὸ | λῆμμα δείκνυται Netz : [τοῦτο γὰρ ἐν | λήμματι δείκνυται] Heiberg || 217 ἁ … ποτὶ *dorice scripsi* : ἡ … πρὸς C || 218 ἁ … ποτὶ … ἴσα *dorice scripsi* : ἡ … πρὸς … ἴση C || 219 ἁ … τῶι … ἁ *dorice scripsi* : ἡ … τῆι … ἡ C || 220 ποτὶ … ἁ … ποτὶ *dorice scripsi* : πρὸς … ἡ … πρὸς C

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καὶ ἔστι τὸ N σαμεῖον κέντρον
τοῦ βάρεος τᾶς MΞ εὐθείας, ἐ-
πείπερ ἴσα ἐστὶν ἁ MN τᾶι NΞ,
αἴ κα ἄρα τᾶι ΞO ἴσαν θέωμες τὰν
HT <περὶ> κέντρον τοῦ βάρεος αὐτᾶς τὸ
Θ, ὅπως ἴσα <ἦι> ἁ TΘ τᾶι ΘH, ἰσορ-
ροπήσει ἁ TH τᾶι MΞ αὐτοῦ με-
νούσαι διὰ τὸ ἀντιπεπονθότως
τετμᾶσθαι τὰν ΘN τοῖς TH MΞ
βάρεσιν, καὶ ὡς τὰν ΘK ποτὶ KN,
οὕτως τὰν MΞ ποτὶ [τὴν] HT· ὥσ-
τε τοῦ ἐξ ἀμφοτέρων βάρεος κέν-
τρον ἐστὶν τοῦ βάρεος τὸ K. ὁμοί-
ως δὲ καὶ ὅσαι κα ἀχθῶσιν
ἐν τῶι ZAΓ τριγώνωι παράλλα-
λοι τᾶι EΔ, ἰσορροπησοῦντιν αὐ-
τοῦ μενούσαι[ς] ταῖς ἀπολαμβα-
νομέναις ἀπ' αὐτᾶν ὑπὸ τᾶς
τομᾶς μετενεχθείσαις περὶ
<κ>ἐ<ν>τ̣ρ̣ο̣ν̣ τ̣ο̣ῦ βά<ρεος τὸ Θ>. καὶ
<ἐσσεῖται τοῦ ἐξ ἁπάντω>ν̣ <β>α̣-

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221 ἔστι Netz : ἐ̣π̣ε̣ὶ̣ Heiberg *σαμεῖον dorice scripsi* : σημεῖον C || 222 *βάρεος τᾶς dorice scripsi* : *βάρους τῆς* C || 222-3 ἐ|*πείπερ* Netz : ἐ̣σ̣τ̣ι̣ν̣ | ἐπειπ̣ε̣ρ̣ Heiberg || 223 *ἴσα … ἁ … τᾶι dorice scripsi* : *ἴση … ἡ … τῆι* C || 224 *αἴ κα … τᾶι … ἴσαν θέωμες dorice scripsi* : *ἐὰν … τῆι … ἴσην θῶμεν* C *τὰν scripsi* : *τὸ* Netz : *τ̣ὴ̣ν̣* Heiberg || 225 HT *scripsi* : NT Netz : TH Heiberg <*περὶ*> *κέντρον scripsi* : *κέντρον* Nezt : *κ̣α̣ὶ̣ κέντρον* Heiberg *βάρεος αὐτᾶς dorice scripsi* : *βάρους αὐτῆς* C || 226 *ἴσα dorice scripsi* : *ἴση* C <*ἦι*> *suppl.* Heiberg *ἁ … τᾶι dorice scripsi* : *ἡ … τῆι* C || 227 *ἁ dorice scripsi* : *ἡ* C TH Netz : TΘ̣H Heiberg *τᾶι dorice scripsi* : *τῆι* C || 227-8 *με|νούσαι dorice scripsi* : *με|νούσηι* C || 229 *τετμᾶσθαι τὰν dorice scripsi* : *τετμῆσθαι τὴν* C || 230 *τὰν … ποτὶ dorice scripsi* : *τὴν … πρὸς* C || 231 *τὰν … ποτὶ dorice scripsi* : *τὴν … πρὸς* C [*τὴν*] *seclusi* || 232 *βάρεος dorice scripsi* : *βάρους* C || 233 *βάρεος dorice scripsi* : *βάρους* C || 234 *κα dorice scripsi* : *ἂν corr.* Heiberg : *ἐὰν* C || 235-6 *παράλλα|λοι dorice scripsi* : *παράλλη|λοι* C || 236 *τᾶι dorice scripsi* : *τῆι* C EΔ *corr.* Heiberg : HΔ C *ἰσορροπησοῦντιν dorice*

scripsi : ἰσορροπήσουσιν C || 237 μενούσαι[ς] *corr.* Heiberg || 238 αὐτᾶν … τᾶς *dorice scripsi* : αὐτῶν … τῆς C || 239 τομᾶς *dorice scripsi* : τομῆς C περὶ Netz : ἐ̣π̣ὶ̣ τ̣ὸ̣ Heiberg || 240 <κ>έ̣<ν>τ̣ρ̣ο̣ν̣ τ̣ο̣ῦ̣ βά<ρους τὸ Θ>. καὶ Netz, *a me dorice rescriptum* : *lineae nihil legit* Heiberg || 241 <ἔσται τοῦ ἐξ ἀπάντω>ν̣ <β>α̣ *mihi dixit* Netz *ipse*, *a me dorice rescriptum* : <ἔσται τοῦ ἐκ πάντων τῶ>ν̣ <β>α̣ Netz : *lineam in hoc loco non recognovit* Heiberg

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ρέων κέντρον τοῦ βάρεος τὸ Κ.
καὶ ἐπεὶ ἐκ μὲν τᾶν ἐν τῶι ΖΑ<Γ>
τριγώνωι <τὸ ΖΑΓ τρίγωνον> συνέστακεν, ἐκ δὲ τᾶν
ἐν ταῖι τομαῖι ὁμοίως ταῖι ΟΞ λαμ-
βανομενᾶν συνέστακε τὸ ΑΒΓ
τμᾶμα, ἰσορροπήσει ἄρα τὸ
ΖΑΓ τρίγωνον αὐτοῦ μένον τῶι
τμάματι τᾶς τομᾶς τεθέν-
τι περὶ κέντρον τοῦ βάρεος τὸ Θ
κατὰ τὸ Κ σαμεῖον, ὥστε τοῦ ἐ-
ξ ἀμφοτέρων κέντρον εἶμεν
τοῦ βάρεος τὸ Κ. τετμάσθω δὲ
ἁ ΓΚ τῶι Χ, ὡς τριπλασίαν
εἶμεν τὰν ΓΚ τᾶς ΚΧ· ἐσσεῖται ἄρα
τὸ Χ σαμεῖον κέντρον τοῦ βάρεος 438
τοῦ ΑΖΓ τρίγωνου· τοῦτο γὰρ δείκν<υ>ται

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242 *ρέων dorice scripsi* : *ρῶν* C *κέντρον corr.* Heiberg : *κέντρων* C *βάρεος dorice scripsi* : *βάρους* C || 243 *τᾶν dorice scripsi* : *τῶν* C ΖΑ<Γ> Netz : Γ̣Ζ̣Α̣ Heiberg || 244 <*τὸ* ΖΑΓ *τρίγωνον*> *scripsi* : <*τὸ* ΓΖΑ *τρίγωνον*> *suppl.* Heiberg *συνέστακεν … τᾶν dorice scripsi* : *συνέστηκεν … τῶν* C || 245 *ταῖι τομαῖι ….ταῖι dorice scripsi* : *τῆι τομῆι … τῆι* C ΟΞ Netz : Ξ̣Ο̣ Heiberg || 245-6 *λαμ|βανομενᾶν συνέστακε dorice scripsi* : *λαμ|βανομένων συνέστηκε* C || 247 *τμᾶμα dorice scripsi* : *τμῆμα* C || 248 *μένον τῶι* Heiberg : *μενόντων* Netz || 249 *τμάματι τᾶς τομᾶς dorice scripsi* : *τμήματι τῆς τομῆς* C || 250 *βάρεος dorice scripsi* : *βάρους* C || 251 *σαμεῖον dorice scripsi* : *σημεῖον* C *τοῦ scripsi* : *τοὺς* Netz : *τ̣ο̣ῦ̣* Heiberg || 252 *εἶμεν dorice scripsi* : *εἶναι* C || 253 *βάρεος … τετμάσθω dorice scripsi* : *βάρους … τετμήσθω* C *δὲ* Nezt : *δ̣ὴ̣* Heiberg || 254 *ἁ dorice scripsi* : *ἡ* C *ὡς τριπλασίαν scripsi* : *ὡς τετραπλασίαν* Netz : *ὥ̣σ̣τ̣ε̣ τριπλασίαν* Heiberg || 255 *εἶμεν τὰν … τᾶς … ἐσσεῖται dorice scripsi* : *εἶναι τὴν … τῆς … ἔσται* C || 256 *σαμεῖον … βάρεος dorice scripsi* : *σημεῖον … βάρους* C || 257 *τοῦ* ΑΖΓ *τρίγωνου scripsi* : *τὸ* ΑΖΓ *τρίγωνον* Netz : *τ̣ο̣ῦ̣* ΑΖΓ̣ *τρίγωνου* Heiberg *τοῦτο γὰρ δείκν<υ>ται* Netz : δεδ̣ε̣ι̣κ̣τ̣α̣ι̣ γ̣ὰ̣ρ̣ Heiberg

66r col. 1

ἐν τοῖς ἰσορροπικοῖς. ἐπεὶ οὖν ἰσορρόπεον τὸ ΖΑΓ τρίγωνον αὐτοῦ μένον τῶι ΒΑΓ τμάματι κατὰ τὸ Κ τεθέντι περὶ τὸ Θ κέντρον τοῦ βάρεος, καί ἐστιν τοῦ ΖΑΓ τριγώνου κέντρον βάρεος τὸ Χ, ἔστιν ἄρα ὡς τὸ ΑΖΓ τρίγωνον ποτὶ τὸ ΑΒΓ τμᾶμα κείμενον περὶ τὸ Θ κέντρον, οὕτως ἀ ΘΚ ποτὶ ΧΚ. τριπλασία δέ ἐστιν ἀ ΘΚ τᾶς ΚΧ· τριπλάσιον ἄρα καὶ τὸ ΑΖΓ τρίγωνον τοῦ ΑΒΓ τμάματος· ἔστι δὲ καὶ τὸ ΖΑΓ τρίγωνον τετραπλάσιον τοῦ ΑΒΓ τριγώνου διὰ τὸ ἴσαν εἶμεν τὰν μὲν ΖΚ τᾶι ΚΑ, τὰν δὲ ΑΔ τᾶι ΔΓ· ἐπίτριτον ἄρα ἐστὶν τὸ ΑΒΓ τμᾶμα τοῦ ΑΒΓ τριγώνου. [τοῦτο γοῦν φανερόν.] figura

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258 ἐπεὶ *corr.* Heiberg : ἔσται C || 258-9 ἰ|σορρόπεον *dorice scripsi* : ἰ|σόρροπον C || 260 τμάματι *dorice scripsi* : τμήματι C || 262 βάρεος *dorice scripsi* : βάρους C || 263 βάρεος *dorice scripsi* : βάρους C || 264 ποτὶ *dorice scripsi* : πρὸς C || 265 τμᾶμα *dorice scripsi* : τμῆμα C || 266 ἀ … ποτὶ *dorice scripsi* : ἡ … πρὸς C || 267 ἀ … τᾶς *dorice scripsi* : ἡ … τῆς C || 269 τμάματος *dorice scripsi* : τμήματος C || 271 ἴσαν εἶμεν *dorice scripsi* : ἴσην εἶναι C || 272 τὰν … τᾶι … τὰν … τᾶι *dorice scripsi* : τὴν … τῆι … τὴν … τῆι C || 273-4 τμᾶ|μα *dorice scripsi* : τμῆ|μα C || 274-5 [τοῦτο γοῦν φανερόν.] *praeeunte* Heiberg *seclusi* : τοῦτο γοῦν φα<νε>ρόν. Netz : [τοῦτο οὖν φανερόν ἐστιν.] Heiberg || 275 figura *post lineam* 275 *figura mathematica statim apparet*

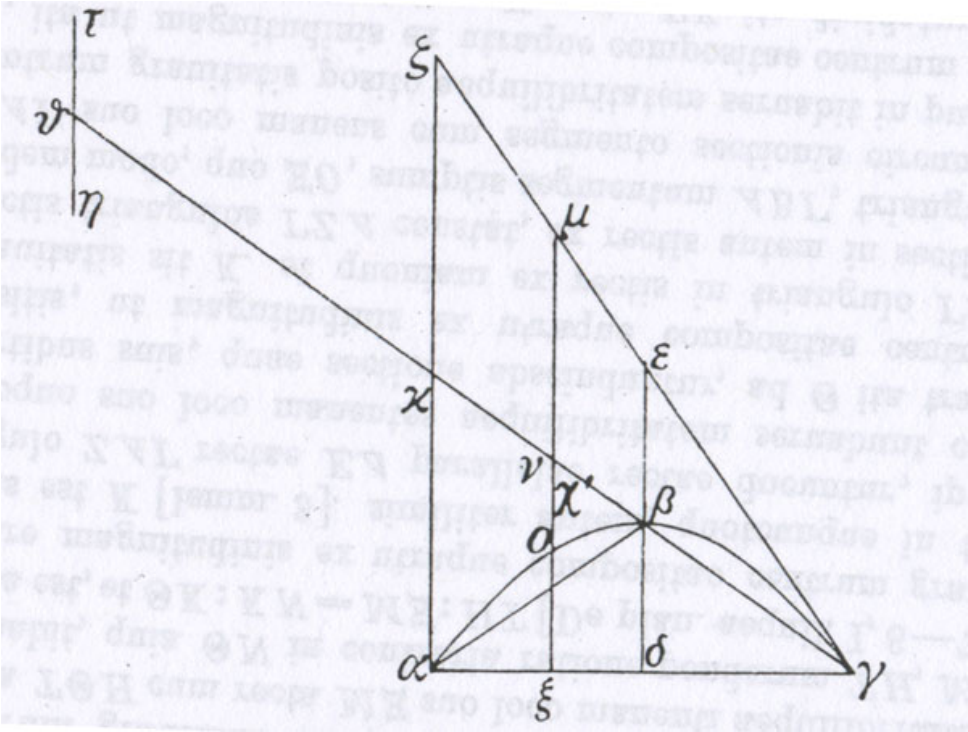

Illustration 12: Heiberg Diagram for *Ephodos* 1.[39]

[39] Heiberg (1913: 435).

71v col. 1

/ [T]τοῦτο δὴ διὰ μὲν τῶν νῦν εἰρημένων prop. 2
οὐκ ἀποδέδεικται, ἔμφασιν δέ
τινα πεποίηκε τὸ συμπέρασμα
ἀληθὲς εἶμεν· διόπερ ἁμὲς ὁ-
ρῶντες μὲν οὐκ ἀποδεδειγμέ-
νον, ὑπονοέοντες δὲ τὸ συμπέ-
ρασμα ἀληθὲς εἶμεν, <ἐ>τάξο-
μες τὰν γεωμετρεομέναν ἀ-
πόδειξιν ἐξευρόντες αὐτοὶ τὰν
ἐ<κ>δοθεῖσαν πρότερον. / ὅτι δὲ πᾶ-
σα σφαῖρα τετραπλασία ἐστὶν τοῦ
κώνου τοῦ βάσιν μὲν ἔχοντος

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276 *β′. in linea nova ante* τοῦτο *scr.* Heiberg [T] *seclusunt omnes* : Τοῦτο C || 279 εἶμεν *dorice scripsi* : εἶναι C ἁμὲς *dorice scripsi* : ἡμεῖς C || 281 ὑπονοέοντες *dorice scripsi* : ὑπονοοῦντες C || 282 εἶμεν *dorice scripsi* : εἶναι C || 282-3 <ἐ>τάξο|μες *futurum doricum ex* ἐτάζω *scripsi* : ἐτάζο|ντες *scr.* Arendt : τάξο|μεν C || 283 τὰν γεωμετρεομέναν *dorice scripsi* : τὴν γεωμετρουμένην C || 284 ἐξευρόντες C : ἐξευρόμες *scr.* Arendt αὐτοὶ C : αὐτοῦ *scr.* Arendt τὰν *dorice scripsi* : τὴν C || 285 ἐ<κ>δοθεῖσαν *scripsi* : ἐδοθεῖσαν Netz : ἐκδοθεῖσαν Heiberg || 286 τετραπλασία *corr.* Heiberg : διπλασία C

| 426 Archimedes' *On Mechanical Theorems to Eratosthenes*. [or] *Approach*.

Archimedes to Eratosthenes, greetings.

I sent you earlier <the enunciations> of the discovered theorems after copying the enunciations themselves, saying that [you should] discover those proofs, which I did not state at that time. The enunciations of the sent theorems were these: <enunciation> of the first <theorem>: if into a right prism having a parallelogram[40] as a base a cylinder is inscribed, having its bases in opposite parallelograms and touching in respect to the sides <of the prism> the remaining four planes, and through the center of the circle, which is a base of the cylinder, and <through> one side of the square in the opposite plane a plane is drawn, the drawn plane will cut off from the cylinder a section, which is bounded by two planes and a surface of a cylinder – the one the drawn plane, the other the plane in which the base of the cylinder is, and the surface between the aforesaid planes – so that the section cut off from the cylinder is a sixth part of the whole prism. Of the second theorem the enunciation was this: that if into a cube is inscribed a cylinder having its bases at opposite parallelograms and touching in respect to its surface the remaining four planes | 428 and also another cylinder is inscribed into the same cube[41] having its bases in opposite parallelograms and touching in respect to its surface the remaining four planes, the figure bounded by the surfaces of the cylinders, which is in both cylinders, is two-thirds of the whole cube.

Those theorems happen to differ from the ones discovered previously; for in respect to the latter figures, the conoids and spheroids and their segments, we compare the same things to each other and to cones and cylinders, but none of them has been found to be equal to a solid figure bounded by planes. But of these figures the first bounded by two planes and a surface of a cylinder and the other by surfaces of cylinders,

[40] As Heiberg (1913: 427.n1) notes, Archimedes writes παραλλαλόγραμμον here but he obviously intends the bases to be squares from *Ephodos* 25. We should understand the opaqueness as the Archimedean concern for the generality of the initial presentation.

[41] The usual rhetorical contrast between αὐτός and ἄλλος.

each of them is found equal to a solid figure bounded by planes. The proofs of these theorems I send you, having written them in this book.

Seeing that you, just as I said[42], are learned and remarkably preeminent in philosophy and have appreciated happenstance[43] contemplation in mathematics, I thought it good to write to you and to furnish in the same book a characteristic of a certain manner, for one traversing along which it will be possible to supply starting points for the ability to contemplate some of the things in mathematics through mechanics.[44] This, I am persuaded, is useful for nothing less than for the proof of the theorems themselves. For certain of those things that earlier appeared clear to me mechanically later were proven geometrically[45] on account of the fact that the contemplation via this way is without proof. For it is easier for one anticipating through this way a certain recognition of the technical problem to supply the proof | 430 more than to seek it though nothing is known. Wherefore in respect to the discoveries of these theorems of both the cone and the pyramid whose proof Eudoxus first published, [namely] that the cone is a third part of the cylinder and the pyramid of the prism, the <bounding figures> having a base the same and equal height, no small part might one assign Democritus who first declared the result about the aforesaid figure without proof.[46] And for me it happens that the discovery of the theorem now being published[47] happens to have been like the earlier ones. I did wish

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[42] Presumably in the previous letter to Eratosthenes.

[43] *ὑποπίπτειν* is an Archimedean word expressing casual indifference to the seriousness of mathematics, as if Archimedes were a dilettante. It appears again in *Ephodos* 118-9 and *On the Sphere and Cylinder* 2.7.

[44] The metaphorical context of this sentence is clearly that of a journey: *ἐπιπορευομένωι*, *ἀφορμὰς*, *ἐφοδιάσας*, *θεωρεῖν*. Archimedes refrains from direct reference to *ὁδός*, the central concept of the metaphor, instead preferring such vague language such as *τρόπου τινὸς ἰδιότητα*.

[45] Arendt (1914: 293) points out that our expectation as first-horizon readers is that only the area of the parabola in *Quadrature of the Parabola* has been proven in the way Archimedes describes, despite his use of the plurals.

[46] Diels-Kranz *Fragmente der Vorsokratiker* Democritus A164-5. Dijksterhuis (1987: 314n.3): "It has struck students that Archimedes uses the singular here, whereas he first referred to theorems on the cone and the pyramid. It does not, however, seem likely that any inferences can be made from this."

[47] Dijksterhuis' (1987: 314n.3) note on scholarly befuddlement about Archimedes' use of the singular to apply to both of Democritus' efforts seems equally applicable to the propositions about the cylinder-hoof and bicyclinder, since most scholars are equally phlegmatic about the distinction between singular and plural. Heiberg (1913: 431) suggests emending to *τῶν νῦν ἐκδιδομένων θεωρημάτων* in his apparatus but does not print it in his main text. Reinach (1907) translates a plural in his French but appends a note (1907: 916n.2): "Le texte dit: "ce théorème", peut-être, comme me le fait observer M. R. Prévost, parce que le

to publish it, describing the manner, both because of having spoken about it before, in order that I not seem to anyone to have spread an empty rumor, and at the same time being convinced that it would contribute no small usefulness to mathematics. For I suppose that some either of those living or of our descendents will discover other not yet suspected theorems through the proven[48] manner. Therefore I first write what first became clear through mechanics, that any segment of a section of an orthogonal cone is four-thirds of a triangle which has the same base and an equal height, and after this each of the things considered by the same manner. At the end of the book I write the geometrized[49] … enuciations I sent. Farewell.

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second théorème n'est, au fond, qu'un corollaire du premier." Reinach's (1907) suggestion seems strained. Mugler (1971: 84) translates a plural but prints the singular (his Greek text is a reprint of Heiberg's (1913) text).

[48] If this refers to the mechanical method as seems likely, the use of *ἀποδεικνύναι* challenges the strict division we would like to construct between the appearance of a result via the mechanical method and the soundness of proof in the geometrical method. A move to rescue the division might emend to *ἐπιδειχθέντος*. But the text should be retained because it runs contrary to expectations. In spite of his philological concern for the proper meaning of words, Knobloch (2000: 92) ignores the problem when he translates *τοῦ ἀποδειχθέντος τρόπου* as "the method made evident."

[49] Dijksterhuis (1987: 315n.4), working from Heiberg's (1913) text, assumes that the geometric 'proofs' referred to are those for the cylinder hoof and the bicylinder. This seems to be the *communis opinio.* Older commentators assume that other proofs are present at the end of the treatise; see chapter 3.3.3.

The reading of the last word is still an open question because both Netz et al. (2008) and Heiberg (1913) dot their reading of the final letter, *ο̣* and *ι̣* respectively, before the lacuna, a gap of at least two lines when Heiberg examined the text in 1906-08 and since grown to include several lines on the next folium. Netz et al. (2008) read nothing beyond the omicron in *γεωμ<ετρ>ο̣<υ|μένας>* for line 19 on 57r1 (line 20 begins at -*<μένας>*) and read nothing on 64v1 until line 4, in the middle of the first axiom. Heiberg's (1913: 430.24-26) text continues *τὰς γεωμετρι<κὰς ἀποδείξεις ἐκείνων τῶν>* | *<θεωρημάτων ὧν τὰς προ>*| 64v1 *τάσεις ἀπεστείλαμεν <σοι πρότερον>* (this passage illustrates Heiberg's (1913) strange editorial practice of dotting letters he supplements in angle brackets). In his apparatus *ad loc.* Heiberg (1913) notes that his supplement was inspired by Théodore Reinach "*suppleui praeeunte Theodoro Reinach*". Heiberg (1913) seemingly refers to Reinach (1907), but I find nothing in that work which bears on this point. I do not print Reinach's suggestions because I believe that his line 130 is too short at 21 characters, when most lines of the *Ephodos* text in the palimpsest are between 25-30 characters.

Heiberg-Zeuthen (1907: 324), written before Reinach (1907), translates "am Schluß des Buches legen wir die dar die geometrische [Beweise der genannten Lehrsätze]…", which is supplemented as if Heiberg-Zeuthen (1907) understood *τὰς γεωμετρι<κὰς ἀποδείξεις τῶν εἰρημένων>* | *<θεωρημάτων …>*. Archimedes refers to *τὴν γεωμετρουμένην ἀπόδειξιν* at *Ephodos* 283-4=Netz et al. (2008: 71v1.8)=Heiberg (1913: 438.20), which is possibly why Heiberg supplied *ἀποδείξεις* in his edition (1913: 430.24-5) here at the lacuna. Other possibilities for the attributed noun if it is accusative include the obvious *ἀποδείξεις*, *θεωρίας*, *προτάσεις*. Taking *τὰς* as genitive would be to understand it as a Doric form, of which dialect there are no other surviving traces in the *Ephodos*. (I do not know if the grave accent on *α* can be read in the palimpsest or is supplied.)

If from a magnitude a magnitude is taken away and the same point is the center of the weight of both the whole and | 432 of the <magnitude> taken away, the same point is the center of the weight of the remaining <magnitude>.

If from a magnitude a magnitude is taken away and the same point is not the center of the weight of both the whole magnitude and the magnitude taken away, the center of the weight of the remaining magnitude is upon the straight line joining the centers of weight of both the whole magnitude and the <magnitude> taken away after <the straight line> has been extended, with also a certain <straight line> having been taken away from it and having to the <straight> line between the aforesaid centers of the weight that ratio which the weight of the magnitude taken away has to the weight of the remaining magnitude.[50]

If the center of the weight of howeverso many magnitudes are upon the same straight line, the center of the weight of the magnitude composed of all <magnitudes> will be upon the same straight line.[51]

The center of the weight of any straight line is the point of bisection of the straight line.[52]

The center of the weight of any triangle is the point at which the straight lines drawn from the angles of the triangle to the middle of the sides cross each other.[53]

The center of the weight of any parallelogram is the point at which the diameters coincide.[54]

The center of the weight of any circle is <the point> which is also the center of the circle.

The center of the weight of any cylinder is the point of bisection of the axis.

The center of the weight of any prism is the point of bisection of the axis.

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[50] Proved in *Equilibrium of Planes* 1.8, 138.19-140.15.
[51] Assumed in *Equilibrium of Planes* 1.4, 128.11-130.3.
[52] Proved in *Equilibrium of Planes* 1.4, 128.11-130.3.
[53] Proved in *Equilibrium of Planes* 1.14, 158.8-162.12.
[54] Proved in *Equilibrium of Planes* 1.10, 142.21-146.2, for which there are two proofs.

The center of the weight of any cone is upon | 434 the axis divided so that the part near the vertex is triple that of the remaining <part>.

I employ also this theorem: if however many magnitudes equal in multitude to other magnitudes when ordered likewise two by two have the same ratio and the first magnitudes, either all or some of them, are to other magnitudes in however many ratios and the latter magnitudes are to the corresponding <magnitudes> in the same ratios, all the first magnitudes will have the same ratio to all the <magnitudes> being enunciated that all the latter magnitudes have to all the <magnitudes> being enunciated.[55]

Let there be a segment the ΑΒΓ, bounded by a straight line, the ΑΓ, and a section of an orthogonal cone, the ΑΒΓ, and let the <straight line> ΑΓ have been cut at the <point> Δ, and parallel to the diameter let have been drawn the <straight line> ΔΒΕ, and let have been joined the <straight lines> ΑΒ, ΒΓ.

I say that the segment ΑΒΓ is four-thirds of the triangle ΑΒΓ.

Let have been drawn from the points Α, Γ first the <straight line> ΑΖ parallel to the <straight line> ΔΒΕ, and second the <straight line> ΓΖ tangent to the section, and let have been extended the <straight line> ΓΒ and let it have cut the <straight line> ΑΖ at the <point> Κ, and let the <straight line> ΚΘ lie equal to the <straight line> ΓΚ, and let be imagined <as> a balance the ΓΘ and <let it be imagined> that the <point> Κ remains stationary and <let there be imagined> parallel to the <straight line> ΕΔ an arbitrary <straight line>, the ΜΞ.

| 436 Therefore since the ΓΒΑ is a parabola[56] and the <straight line> ΓΕ is tangent and the <straight line> ΓΔ is an ordinate, the <straight line> ΕΒ is equal to the <straight

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[55] Proved as the first proposition in *On Conoids and Spheroids*. Netz, Saito, and Tchernetska (2001: 19-20) translate this postulate differently: "If however many magnitudes have the same ratio (equal <to them> by multitude), two by two, with other magnitudes similarly ordered, and the first magnitudes – whether all or some of them – are to other magnitudes in however many ratios, and the latter magnitudes are in the same ratios to other magnitudes, respectively, <then> all the first magnitudes to all the <magnitudes> they stand in ratio to, have a ratio that all the latter magnitudes have to all the <magnitudes> they stand in ratio to." I see in λεγόμενα the technical use of λέγειν in enunciation of the mathematical proof.

[56] παραβολή here, as Heiberg (1913: 437n.1) notes, is a later interpolation for Archimedes' older terminology, ὀρθογωνίου κώνου τομά.

line> BΔ, for this is proved in the <*Conic*> *Elements*.[57] So on account of this and the fact that the <straight lines> ZA, MΞ are parallel to the <straight line> EΔ , the <straight line> MN is equal to the <straight line> NΞ and the <straight line> ZK <is equal to> the <straight line> KA. And since as the <straight line> ΓA <is> to <the straight line> AΞ, so the <straight line> MΞ <is> to <the straight line> ΞO. And as the <straight line> ΓA <is> to <the straight line> AΞ, so the <straight line> ΓK <is> to <the straight line> KN, and the <straight line> ΓK is equal to the <straight line> KΘ, therefore as the <straight line> ΘK <is> to <the straight line> KN, so the <straight line> MΞ <is> to <the straight line> ΞO. And the point N is the center of weight of the straight line MΞ, since the <straight line> MN is equal to the <straight line> NΞ; therefore if we set equal to the <straight line> ΞO the <straight line> HT around its center of weight, the <point> Θ, so that the <straight line> TΘ is equal to the <straight line> ΘH, the <straight line> TH will balance the <straight line> MΞ, which will remain stationary, on account of the fact that the <straight line> ΘN has been cut inversely proportional to the weights TH, MΞ, and as the <straight line> ΘK <is> to <the straight line> KN, so the <straight line> MΞ <is> to the <straight line> HT. Therefore the <point> K is the center of the weight of the weight from both. Similarily, however many <straight lines> parallel to the <straight line> EΔ are drawn in the triangle ZAΓ they will balance and remain stationary by the <straight lines> cut off from them by the section after <the straight lines> have been transferred around the center of the weight, the <point> Θ. And the <point> K will be the center of the weight of all weights. And since first the triangle ZAΓ has been composed of the <straight lines> in the triangle ZAΓ, and second the segment ABΓ has been composed of the <straight lines> taken in the segment similar to the <straight line> OΞ, therefore the triangle ZAΓ will balance and remain stationary at the point K by the segment of the section set around the center of the weight, the <point> Θ, so that the <point> K is the center of the weight of the <weight> of both. And let the <straight line> ΓK have been cut by the <point> X, so that the <straight line> ΓK is triple of the <straight line> KX; therefore | 438 the point X will be the center of the weight of the triangle AZΓ. For this

[57] Either of Euclid or Aristeaus the Elder.

is shown in the *Equilibria*.[58] Since therefore the triangle ZAΓ is balanced, remaining stationary at the <point> K by the segment BAΓ which was set at the <point> Θ, the center of the weight, and the <point> X is the center of the weight of the triangle ZAΓ, therefore as the triangle AZΓ is to the segment ABΓ lying around the <point> Θ <as> its center, so the <straight line> ΘK <is> to <the straight line> XK. Therefore the <straight line> ΘK is triple of the <straight line> KX; and therefore also the triangle AZΓ is triple of the segment ABΓ. And also the triangle ZAΓ is fourfold of the triangle ABΓ on account of the fact that the <straight line> ZK is equal to the <straight line> KA and the <straight line> AΔ is equal to the <straight line> ΔΓ: therefore the segment ABΓ is four-thirds of the triangle ABΓ.

So this was not proven by what was now said but still creates a certain impression that the conclusion is true. Wherefore I, seeing that <the conclusion> is not proven but nonetheless suspecting that the conclusion is true, will test [it] in respect to the geometrized proof, which was published earlier after I myself discovered it.
That every sphere is fourfold of the cone having its base[59] | 440

[58] What Archimedean work *Equilibria* refers to is not perfectly clear: Heiberg (1913: 439n.1) took the title to refer to *Equilibrium of Planes*, but non-extant Archimedean works on the basics of mechanical geometry are possible, such as *On Balances*.
[59] The sixteeth column ends mid-enunciation of the second proposition. This enunciation is attached directly to the entire proposition, unlike the enunciation of proposition 1.

Appendix C

Prosopography of Physicians with Hellenistic Sect Affiliation

I give here a comparative chronological table of the dates of activity of the physicians known from the three main Hellenistic medical sects: the Empiricists, the Herophileans, and the Erasistrateans.

Empiricists	Herophileans	Erasistrateans[60]
	Herophilus of Chalcedon 330/320-260/250 BCE[61]	Erasistratus of Ioulis c.315-240 BCE[62]
	Callianax *fl.* 260-240 BCE[63]	Strato *fl.* 265-245 BCE[64]
Philinus of Cos *fl.* 250 BCE[65]	Andreas of Carystus *fl.* 245-217 BCE[66]	Apollonius of Memphis *fl.* 250-200 BCE[67]

[60] Knowledge of the members and fragments of the Erasistrateans is in a state of relative scholarly neglect compared to the Empiricists and Herophileans. The identifications in this column are taken from Keyser and Irby-Massie's (2008) *Encyclopedia of Ancient Natural Scientists*. (Compare also Garofalo (1988: 4-5).) Yet the dates given in this book ought to be treated with caution since some are demonstrably inflated and the identifications in their list of Erasistrateans (2008: 1006-1011) include some physicians known *not* to be Erasistrateans by affiliation, only family members or teachers of Erasistratus. Such mistaken listings and dates include Medeios (2008: 536), Khrysippos of Knidos II (2008: 475), Kleophantos of Ioulis (2008: 483), and Antigenes (2008: 92); see Appendix D for these figures. Medeios was the uncle of both Kleophantos and Erasistratus and thus not an Erasistratean; Khrysippos of Knidos II is said to have taught Medeios, Kleophantos, and Erasistratus and thus cannot have lived or flourished 280-250 BCE as claimed; Kleophantos of Ioulis was Erasistratus' brother and known to have his own students such as Mnemon of Side and Antigenes (see Appendix D) but Keyser and Irby-Massie (2008) conflate Kleophantos' students with the Erasistrateans. I have listed the fourteen Erasistrateans remaining in Keyser and Irby-Massie's (2008: 1006-1011) list according to the dates given but *caveat lector* until more scholarship is completed on the Erasistrateans. The reader is also cautioned that Keyser and Irby-Massie often give ethnics of the cities associated with the individual's work: this is seriously misleading in the case of Greek colonists to Egypt, some of whose families retained their citizenship in their ancestral Greek cities for several generations before adopting citizenship in an Egyptian town. I give ethnics only when given in ancient source.

[61] Von Staden (1989: 36-50).

[62] Keyser and Irby-Massie (2008: 294-96).

[63] Von Staden (1989: 478).

[64] Keyser and Irby-Massie (2008: 764-65). This doctor is not the Peripatetic Strato of Lampsacus.

[65] Deichgräber (1965: 163).

[66] Von Staden (1989: 472). Court physician to Ptolemy IV Philopater.

[67] Keyser and Irby-Massie (2008: 113-14).

Empiricists	Herophileans	Erasistrateans
Serapion of Alexandria *fl.* 225 BCE[68]	Callimachus of Bithynia *fl.* 230 BCE[69]	Apollophanes of Seleucia *fl.* 223-187 BCE[70]
	Bacchius of Tanagra *fl.* 246-210 BCE[71]	
Zeuxis *fl.* 200-175 BCE[72]	Demetrius of Apamea *fl.* 217-100 BCE[73]	
Glaucias of Tarentum *fl.* 175 BCE[74]	Zeno *fl.* 175 BCE[75]	
Apollonius the Elder *fl.* 175 BCE[76]		Miltiades *fl.* 250-125 BCE[77]
Apollonius Byblas *fl.* 150 BCE[78]		
	Hegetor *fl.* 150-100 BCE[79]	Ptolemaeus *fl.* 250 BCE – 100 CE[80]
Ptolemaeus of Cyrene *fl.* 100 BCE[81]	Mantias *fl.* 165-90 BCE[82]	Hicesius of Smyrna *fl.* 120-80 BCE[83]

[68] Deichgräber (1965: 164-65). Von Staden (1989: 474) dated Serapion's *floruit* to 200 BCE on the basis of his citing Andreas of Carystus (Galen *De comp. medicam. secundum locos* 13.343-4K = Andreas fr. 29 vS = Empiricist fr. 151 D) but in a later article (1997a: 941) returned to Deichgräber's dating.

[69] Von Staden (1989: 481-82).

[70] Keyser and Irby-Massie (2008: 117-18). Court physician to Antiochus III the Great.

[71] Von Staden (1989: 485).

[72] Kudlien (1972).

[73] Von Staden (1989: 508-09), who suggests that this Apamea is the Apamea in Bithynia, home of the Herophileans Herophilus of Chalcedon and Callimachus of Bithynia, rather than the Seleucid Apamea-on-the-Orontes. I am therefore inclined to believe that Demetrius of Apamea ought to date earlier in von Staden's given range rather than later, especially since Fraser (1972: 1.307-08) has argued that most scientists and intellectuals in Alexandria (the early Herophilean sect was an Alexandrian phenomenon) were immigrants or at least of immigrant parents before the expulsion of the intellectuals in 145/4 BCE.

[74] Deichgräber (1965: 168-69).

[75] Von Staden (1989: 505).

[76] Deichgräber (1965: 171).

[77] Keyser and Irby-Massie (2008: 556).

[78] Deichgräber (1965: 172).

[79] Von Staden (1989: 513). Hegetor probably flourished closer to 100 than 150 BCE because both Heraclides of Tarentum and Apollonius of Citium appear to be responding to him as a recent polemicist; see chapter 4.3.4.

[80] Keyser and Irby-Massie (2008: 704). Keyser suggests one reason to include Ptolemaeus under Ptolemaic rule is that the name 'Ptolemaeus' is more common at that time.

[81] Deichgräber (1965: 172).

[82] Von Staden (1989: 515). Teacher of Heraclides of Tarentum; like Hegetor, probably closer to 100 BCE.

[83] Keyser and Irby-Massie (2008: 396).

Empiricists	Herophileans	Erasistrateans
Zophyrus of Alexandria *fl.* 80 BCE?[84]		Artemidorus of Side *fl.* 90-30 BCE[85]
Heraclides of Tarentum *fl.* 75 BCE[86]		Menodorus *fl.* 85-35 BCE[87]
Apollonius of Citium *fl.* 90-70 BCE[88]	Dioscurides Phacas *fl.* 75-30 BCE[89]	Heraclides of Ephesus *fl.* 75-50 BCE[90]
Diodorus *fl.* 60 BCE?[91]		
Lycus of Naples *fl.* 60 BCE?[92]	Chrysermus *fl.* 50-25 BCE[93]	Athenion *fl.* 50-10 BCE[94]
	Zeuxis *fl.* 45-30 BCE[95]	
	Alexander Philalethes 50 BCE - 25 CE[96]	Charidemos *fl.* 50 BCE – 120 CE[97]
	Heraclides of Erythrae *fl.* 50-1 BCE[98]	
Archibius *fl.* 1 BCE?[99]	Apollonius Mys *fl.* 25 BCE – 25 CE[100]	
	Aristoxenus *fl.* 25-50 CE[101]	

[84] Deichgräber (1965: 205).
[85] Keyser and Irby-Massie (2008: 165).
[86] Deichgräber (1965: 172) follows Wellman's dating; Guardosole (1997: 23) also accepts this date.
[87] Keyser and Irby-Massie (2008: 549).
[88] Deichgräber (1965: 206). Court physician to either Ptolemy X Alexander I, Ptolemy XII Auletes, or Ptolemy of Cyprus. See chapter 4.3.4 for further discussion.
[89] Von Staden (1989: 519-20). Court physician to Ptolemy XII Auletes and likely Cleopatra VII.
[90] Keyser and Irby-Massie (2008: 367).
[91] Deichgräber (1965: 203).
[92] Deichgräber (1965: 204). Keyser and Irby-Massie (2008: 514).
[93] Von Staden (1989: 525-6).
[94] Keyser and Irby-Massie (2008: 178).
[95] Von Staden (1989: 531). The Herophilean Zeuxis is not to be confused with the Empiricist Zeuxis.
[96] Von Staden (1989: 532).
[97] Keyser and Irby-Massie (2008: 470).
[98] Von Staden (1989: 555).
[99] Deichgräber (1965: 209). Fabio Stok in Keyser and Irby-Massie (2008: 159-60) redates him to 50-70 CE, although his grounds for doing so are not clear.
[100] Von Staden (1989: 540).
[101] Von Staden (1989: 559).

Empiricists	Herophileans	Erasistrateans
	Cydias *fl.* 50-1 BCE[102]	
	Gaius *fl.* 50 BCE – 50 CE[103]	
Cassius *fl.* 30 CE[104]	Demosthenes Philalethes *fl.* 7 BCE - 50 CE[105]	Hermogenes of Smyrna *fl.* 30-70 CE[106]
Menodotus of Nicomedia *fl.* 125 CE[107]		
Theodas of Laodocia *fl.* 125 CE[108]		
Aischrion of Pergamum *fl.* 125 CE[109]		
Epicurus of Pergamum *fl.* 150 CE[110]		Martialius *fl.* 150-90 CE[111]
Philippus of Pergamum *fl.* 150 CE[112]		
Callicles *fl.* 150 CE?[113]		
Sextus Empiricus *fl.* 200 CE[114]		
Theodosius *fl.* 200 CE[115]		

[102] Von Staden (1989: 564).

[103] Von Staden (1989: 566-67).

[104] Deichgräber (1965: 210). See especially von Staden (1989: 566-67) on Roman names among physicians. Von Staden (1997a) doubts his Empiricist affiliation, noting that he is never called an Empiricist in the ancient evidence.

[105] Von Staden (1989: 575) recognizes him as the last Herophilean.

[106] Keyser and Irby-Massie (2008: 379).

[107] Deichgräber (1965: 212). Note the jump in time: the first century CE belongs to the Pneumatists and Methodists at Rome as the Hellenistic sects decline.

[108] Deichgräber (1965: 214).

[109] Deichgräber (1965: 215).

[110] Deichgräber (1965: 408).

[111] Keyser and Irby-Massie (2008: 535). The Erasistratean *bête noire* of Galen known from *On Prognosis* and *On My Own Books*, his name may be either Martianus or Martialius; cf. Boudon-Millot (2007: 185.n3).

[112] Deichgräber (1965: 408).

[113] Keyser and Irby-Massie (2008: 460) point out that there is an Empiricist physician "Kallikles" mentioned by Galen unknown to Deichgräber's (1965) collection. He is likely to be a contemporary of Galen rather than a Hellenistic physician.

[114] Deichgräber (1965: 216).

[115] Deichgräber (1965: 219).

Appendix D

Prosopography of Physicians without Sect Affiliation
in the Third Century BCE

I have arraigned the physicians without sect affiliation in the third century BCE in a rough chronological order. I leave to the end of the list those names without more secure date than at some time during the third century. I supply an ethnic only if known.

(1) Chrysippus of Cnidos, *d.* 278/7 BCE[116]
(2) Medeios, *fl.* 320-270 BCE[117]
(3) Amyntas, *d.* 278/7 BCE[118]
(4) Nicias of Miletas, *fl.* 275-250 BCE[119]
(5) Dionysius son of Oxymachus, *fl.* 300-250 BCE[120]
(6) Dieuches, *fl.* 300-200 BCE[121]
(7) Dionysius of Ephesus, *fl.* 290-250 BCE[122]
(8) Xenodemus of Syros, *fl.* 300-250 BCE[123]
(9) Diphilus of Siphnus, *fl.* 300-250 BCE[124]
(10) Metrodorus of Amphipolis, *fl.* 275-69 BCE[125]

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[116] PP (=Peremans and van't Dack (1950-81)) 16647. Court physician to Ptolemy Philadelphus? See Gorteman (1957: 321-25) for discussion of name, status, and death. More bibliography is given in Keyser and Irby-Massie (2008: 475) *s.v.* 'Khrysippos of Knidos II' but their dates are wrong if Gorteman is correct.

[117] Keyser and Irby-Massie (2008: 536). The uncle of Erasistratus and perhaps grandson of Aristotle, also a student of Chrysippus of Cnidos.

[118] PP 16573. Doctor at the court of Ptolemy II Philadelphus, put to death in 278/7. See Gorteman (1957: 321-25) for discussion.

[119] Keyser and Irby-Massie (2008: 576-77). Dedicatee of Theocritus *Idylls* 11 and 13. He may have been a student with Erasistratus; cf. *FGrH* 1104.

[120] Keyser and Irby-Massie (2008: 260-61).

[121] Keyser and Irby-Massie (2008: 245-46), teacher of Noumenius of Heracleia. One wonders whether this date is not too late: Dieuches is usually grouped with other dogmatic authors, e.g. Phylotimus and Mnesitheus, who are mid-to-late 4th century authors, possibly post-dating 323, but not much into the third century if it all. On fourth-century medical authors see van der Eijk (2005a).

[122] Keyser and Irby-Massie (2008: 263). He may be identical to Dionysius son of Oxymachus *fl.* 300-250 BCE, no. 5.

[123] Samama (=Samama (2003)) 104. Inscription from Delos.

[124] Keyser and Irby-Massie (2008: 273).

[125] Samama 182. Wellman (1930: 327). Inscription from Ilion. Honored by Antiochus and Seleucus for saving the king from a battle wound. It is unclear whether Metrodorus is a court doctor (as Wellman supposed) or an army physician or a local physician. In favor of Wellman's thesis, Samama (2003: 474.n6) points out that the doctor of Ptolemy III Euergetes, Xe[nophan]tus (see no. 25 below), does not have the title *archiatros*, implying that this court title at least came later.

(11) Philippus of Epirus, *fl.* 270-240 BCE[126]
(12) Apollodorus the Theriacus, *fl.* 280-240 BCE[127]
(13) Cleophantus of Ceos, *fl.* 270-240 BCE[128]
(14) Aristogenes of Cnidos, *fl.* 260-240 BCE[129]
(15) Artemidorus, *fl.* 260-240 BCE[130]
(16) Theopompus, *fl.* 256 BCE[131]
(17) Eudemus, *fl.* 250 BCE[132]
(18) Noumenius of Heracleia, *fl.* 270-230 BCE[133]
(19) Eucarpus, *fl.* 249/8 BCE[134]
(20) Antigenes, *fl.* 250-200 BCE[135]
(21) Neileus, *fl.* 255-215 BCE[136]
(22) Mnemon of Side, *fl.* 250-200 BCE[137]
(23) Demetrius, *fl.* 246 BCE[138]
(24) Neon, *fl.* 242 BCE[139]
(25) Xe[nophan]tus of Alexandria, *fl.* 246-221 BCE[140]
(26) Philippus, *fl.* 240 BCE[141]

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126 Wellman (1930: 322) cites Celsus 3.21 and says he was a court physician to Antigonas Gonatas. Keyser and Massie (2008: 647) deny *s.v.* 'Philippos of Macedon' that Philippos of Epirus and Philippos of Macedon are the same.

127 Keyser and Irby-Massie (2008: 106). Source for Pliny on poisonous animals and perhaps the source of Nicander's *Theriaca*.

128 Keyser and Irby-Massie (2008: 483). Brother of Erasistratus, student of Chrysippus of Cnidos, teacher of Antigenes and Mnemon of Side.

129 Keyser and Irby-Massie (2008: 137). Court physician to Antigonas Gonatas.

130 PP 16582. Fraser (1972: 1.370). Doctor to Apollonius, finance minister to Ptolemies II Philadelphus and III Euergetes, known from the Zenon archive.

131 PP 16609.

132 PP 16599. Keyser and Irby-Massie (2008: 308). Anatomist. Herophilus is his younger contemporary in Gal. 18A.7K. If older than Herophilus, he probably died by mid-century and Keyser and Irby-Massie's *flourit* is too lengthy.

133 Keyser and Irby-Massie (2008: 583). Student of Dieuches.

134 PP 16600.

135 PP 16575. Cleophantian (that is, he was a member of the sect of Erasistratus' brother Cleophantus).

136 Keyser and Irby-Massie (2008: 569). Famous for his improved Hippocratic bench as recorded in Orb. *Coll*. 49.8.

137 PP 16619. Cleophantian (that is, he was a member of the sect of Erasistratus' brother Cleophantus). Keyser and Irby-Massie (2008: 559) suggest that his interpolated markings in [Hipp.] *Epidemics* 3 might have been a native script from Side.

138 PP 16588. Doctor at Oxyrhynchus.

139 PP 16623. Doctor in favor with the king, father of Agathoboulos (PP 15784) who dedicates a statute to Sosibius, the minister of Ptolemy IV.

140 PP 16624. Samama 393. Fraser (1972: 1.370). Honored by a statue erected by Ptolemy III Euergetes. I print Fraser's restoration of the name from the stone, accepted also by Samama.

141 PP 16640, father of Caphisophon.

(27) Caphisophon, *fl.* 240 BCE[142]
(28) Philistos of Cos, *fl.* 241-200 BCE[143]
(29) Phanesis, *fl.* 233/2 BCE[144]
(30) Diagoras of Cyprus, *fl.* 240-220 BCE[145]
(31) Chartadas of Berenice, *fl.* 230 BCE[146]
(32) Archippus of Ceos, *fl.* 230-220 BCE[147]
(33) Nymphodorus, *fl.* 240-220 BCE[148]
(34) Hermias of Cos, *fl.* 219-17 BCE[149]
(35) Demetrius, *fl.* 219/8 BCE[150]
(36) Theiodotus, *fl.* 215/13 BCE[151]
(37) Philon, *fl.* 215/13 BCE[152]
(38) Dicaios, *fl.* 300-200 BCE[153]
(39) Melancomas of Megalopolis, *fl.* 207/6 BCE[154]
(40) Philistos of Cos, *fl.* 204/3 BCE[155]
(41) Papias of Laodicea, *fl.* 250 BCE-90 CE[156]
(42) Perigenes, *fl.* 200 BCE – 50 CE[157]
(43) Pythion, *fl.* 200 BCE[158]
(44) Philippus of Cos, *fl.* 200 BCE[159]
(45) Philon of Sicyon, *fl.* 300-200 BCE[160]

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142 PP 16614. Samama 132. Samama (2003: 241.n42) suggests that he was court doctor to Ptolemy III.
143 Samama 124. Honorific inscription from Cos. Possibly of the same family as Philistos of Cos (*fl.* 200), no. 40.
144 PP 16570. Native Egyptian doctor in Crocodilopolis.
145 Keyser and Irby-Massie (2008: 244) date him from 220-180 BCE, since he is listed between Erasistratus and Andreas by Dioscorides in *de Materia Medica*; if so, his date ought to be more 240-220 BCE since Andreas is dead in 217.
146 Samama 151. Inscription from Calymna.
147 Samama 107.
148 Keyser and Irby-Massie (2008: 584-85). Famous for a mechanical "chest" for dislocations in Orb. *Coll.* 49. One thinks also of his contemporaries Andreas of Carystus and Neileus' mechanical innovations.
149 Samama 126 is an honorific inscription from Gortyn; Samama 127 is an honorific inscription on Cos from Cnossians; Samama 128 is an honorific inscription from Halicarnassus.
150 PP 16589. Doctor at Karanis.
151 PP 16608. Teacher of medicine.
152 PP 16642. Apprentice of Theiodotus.
153 Samama 073. Inscription from Atrax near Larisa.
154 Samama 057. Inscription from Delphi.
155 Samama 056. A dedicatory inscription at Delphi for Philistos, who practiced in Delphi.
156 Keyser and Irby-Massie (2008: 608) suggest a connection with the Autolycus who perished in a shipwreck of 201 BCE, implying a *flourit* of 200 BCE.
157 Keyser and Irby-Massie (2008: 635). A mechanic and surgeon; the double combination suggests an early date to me.
158 Samama 160. Inscription from Minoa.
159 Samama 108, Samama 135.
160 Samama 012. Doctor at Athens.

(46) Xenotimus, *fl.* 300-200 BCE[161]
(47) Anaxippus, *fl.* 300-200 BCE[162]
(48) Hippocrates of Cos, *fl.* 300-200 BCE[163]
(49) Polygnotus of Ceos, *fl.* 300-200 BCE[164]
(50) Idriarchos of Rhodes, *fl.* 300-200 BCE[165]
(51) Nicandros of Halicarnassus, *fl.* 300-200 BCE[166]
(52) Phaidas of Tenedos, *fl.* 300-200 BCE[167]
(53) Noumenios of Soloi, *fl.* 300-200 BCE[168]
(54) Dionysius the Hunchback, *fl.* 300-200 BCE[169]
(55) Philon, *fl.* 300-200 BCE[170]
(56) Nearchus, *fl.* 300-200 BCE[171]
(57) Dikais, *fl.* 300-200 BCE[172]
(58) Theudorus, *fl.* 300-200 BCE[173]
(59) E…es, *fl.* 300-200 BCE[174]
(60) Simylion, *fl.* 300-200 BCE[175]
(61) Tre.. , *fl.* 300-200 BCE[176]
(62) Leon, *fl.* 300-200 BCE[177]
(63) Agias, *fl.* 300-200 BCE[178]
(64) Theodoridas, *fl.* 300-200 BCE[179]
(65) Bakalles, *fl.* 300-200 BCE[180]
(66) Philocles, *fl.* 300-200 BCE[181]

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[161] Samama 123. Honorific inscription from Cos.
[162] Samama 130. Inscription from Cos.
[163] Samama 129.
[164] Samama 162.
[165] Samama 156. Honorific inscription from Astypalaia.
[166] Samama 106.
[167] Samama 371. Inscription from Palaiopaphos.
[168] Samama 372. Inscription from Palaiopaphos.
[169] PP 16593. Originally from Kurtos, an Egyptian village, but also called ὁ κυρτός, i.e. "the Hunchback" in a pun.
[170] Samama 506. A *defixio* tablet from Metaponto cursing the *ergasterion* of seventeen physicians (no. 55-71) so that they cannot work.
[171] Samama 506.
[172] Samama 506. A woman.
[173] Samama 506.
[174] Samama 506.
[175] Samama 506.
[176] Samama 506.
[177] Samama 506.
[178] Samama 506.
[179] Samama 506.
[180] Samama 506.
[181] Samama 506.

(67) …ouchos, *fl.* 300-200 BCE[182]
(68) Terp.. , *fl.* 300-200 BCE[183]
(69) …on, *fl.* 300-200 BCE[184]
(70) Zoilos, *fl.* 300-200 BCE[185]
(71) Xe…, *fl.* 300-200 BCE[186]

[182] Samama 506.
[183] Samama 506.
[184] Samama 506.
[185] Samama 506.
[186] Samama 506.

Bibliography

Acerbi, Fabio. 2007. "Archimedes," *New Dictionary of Scientific Biography*. 85-91.

Adler, Ada. 1931. *Suidae Lexicon: Pars II, Δ-Θ*. Stuttgart.

Allen, James. 2000. *Inferences From Signs: Ancient Debates about the Nature of Evidence*. Oxford.

Amsterdamska, Olga. 1990. "Surely You are Joking, Monsieur Latour!," *Science, Technology, and Human Values* 15.4: 495-504.

Arendt, F. 1914. "Zu Archimedes," *Bibliotheca Mathematica*[3] 14: 289- 311.

Asper, Markus. 2007. *Griechische Wissenschaftstexte*. Stuttgart.

--------. 2009. "Two Mathematical Cultures in Ancient Greece," in *The Oxford Handbook of the History of Mathematics*. E. Robson and J. Stedall *eds*. Oxford. 107-132.

The Athenian Agora: A Guide. 1976. 3rd ed. Athens.

Bagnall, R.S. 1997. "Decolonizing Ptolemaic Egypt" in *Hellenistic Constructs: Essays in Culture, History, and Historiography*. P. Cartledge, P. Garnsey, and E. Gruen *eds*. Berkeley. 225-41.

Barnes, Barry. 2005. "Elusive Memories of Technoscience," *Perspectives on Science* 13.2: 142-65.

Barnes, Barry, David Bloor, John Henry. 1996. *Scientific Knowledge: A Sociological Analysis*. Chicago.

Barnes, Jonathan *ed*. 1982. *Science and Speculation: Studies in Hellenistic Theory and Practice*. Cambridge.

Barton, Tamsyn. 1994a. *Ancient Astrology*. New York.

--------. 1994b. *Power and Knowledge: Astrology, Physiognomics and Medicine under the Roman Empire*. Ann Arbor.

Berryman, Sylvia. 2009. *The Mechanical Hypothesis in Ancient Greek Natural Philosophy*. Cambridge.

Biaglioni, Mario. 1993. *Galileo, Courtier: The Practice of Science in the Culture of Absolutism*. Chicago.

--------. *ed*. 1999. *The Science Studies Reader*. New York.

--------. 2009. "Postdisciplinary Liaisons: Science Studies and the Humanities," *Critical Inquiry* 35: 816-833.

Boudon-Millot, Véronique. 2007. *Galien: Introduction générale, Sur l'ordre de ses propres livres, Sur les propres livres, Que l'excellent médecin est aussi philosophe*. Budé vol. 1. Paris.

Borchardt, Ludwig. 1920. *Die Altägyptische Zeitmessung*. München.

Butterfield, Herbert. 1931. *The Whig Interpretation of History*. London.

Callon, Michel. 1986. "Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St. Brieuc Bay," in *Power, Action and Belief: A New Sociology of Knowledge?* J. Law *ed*. London. 196-229.

Cameron, Alan. 1995. *Callimachus and His Critics*. Princeton.

Cambiano, Giuseppe. 1992. "Scoperta e dimonstrazione in Archimede," *Archimede: mito, tradizione, scienza*. C. Dollo *ed*. Firenze. 21-41.

Cuomo, Serafino. 2002. "The machine and the city: Hero of Alexandria's Belopoeica," in *Science and Mathematics in Ancient Greek Culture*. C.J. Tuplin and T.E. Rihll *eds*. Oxford. 165-77.

--------. 2007. *Technology and Culture in Greco-Roman Antiquity*. Cambridge.

Daston, Lorraine. 1998. "The Nature of Nature in Early Modern Europe," *Configurations* 6.2: 149-72.

--------. 2000. "Introduction: The Coming into Being of Scientific Objects," in *Biographies of Scientific Objects*. L. Daston *ed*. Chicago. 1-14.

--------. 2009. "Science Studies and the History of Science," *Critical Inquiry* 35: 798-813.

Daston, Lorraine and Peter Galison. 2007. *Objectivity*. New York.

De Lacy, Phillip. 1981. *Galen: On the Doctrines of Hippocrates and Plato*. vol. I. CMG 4.1.2. Berlin.

Deas, Henry Thomson. 1931. "The Scholia Vetera to Pindar," *HSCP* 42: 1-78.

Deichgräber, Karl. 1965. *Die griechische Empirikerschule: Sammlung der Fragmente und Darstellung der Lehre*. 2nd ed. Berlin.

--------. 1984. "Galen als Erforscher des Menschlichen Pulses" in *Ausgewählte Kleine Schriften*. Hildesheim. 288-326.

Denniston, J.D. 1950. *Greek Particles*. Oxford.

Dijksterhuis, E.J. 1987. *Archimedes*. Including "Archimedes After Dijksterhuis: A Guide to Recent Studies" by W.R. Knorr. Princeton.

Dindorf, Ludwig. 1831. "ἀπάραυξος," in *Thesaurus Linguae Graecae*. Paris. 1.2: 1193.

Drachmann, A.G. 1948. *Ktesibios, Philon and Heron: A Study in Ancient Pneumatics*. Copenhagen.

--------. 1967. "Archimedes and the Science of Physics," *Centaurus* 12.1: 1-11.

Flemming, Rebecca. 2000. *Medicine and the Making of Roman Women: Gender, Nature, and Authority from Celsus to Galen*. Oxford.

--------. 2003. "Empires of knowledge: medicine and health in the Hellenistic world" in *The Blackwell Companion to the Hellenistic World*. A. Erskine *ed*. Oxford. 449-63.

--------. 2007. "Galen's imperial order of knowledge," in *Ordering Knowledge in the Roman Empire*. J. König and T. Whitmarsh *eds*. Cambridge. 241-77.

--------. 2009. "Demiurge and Emperor in Galen's world of knowledge," in *Galen and the World of Knowledge*. C. Gill, T. Whitmarsh, and J. Wilkins *eds*. Cambridge. 59-84.

Forman, Paul. 2007. "The Primacy of Science in Modernity, of Technology in Postmodernity, and of Ideology in the History of Technology," *Technology and History* 23.1/2: 1-153.

--------. 2010. "(Re)cognizing Postmodernity: Helps for Historians – of Science Especially," *Berichte zur Wissenschaftsgeschichte* 33.2: 157-175.

Frede, Michael, tr. 1985. *Galen: Three Treatises on the Nature of Science*. Indianapolis.

--------. 1987. "The Empiricist Attitude towards Reason and Theory," in *Method, Medicine, and Metaphysics*. R.J. Hankinson *ed*. Edmonton. 79-97.

--------. 1990. "An empiricist view of knowledge: memorism," in *Epistemology: Cambridge Companions to Ancient Thought*. S. Everson *ed*. Cambridge. 225-250.

Fraser, P.M. 1975. *Ptolemaic Alexandria*. 3 vols. Oxford.

Garofalo, Ivan. 1988. *Erasistrati Fragmenta*. Pisa.

Geertz, Clifford. 1973. *The Interpretation of Cultures: Selected Essays*. New York.

Geus, Klaus. 2002. *Eratosthenes von Kyrene: Studien zur Hellenistischen Kultur- und Wissenschaftsgeschichte*. München.

Gibson, Sophie. 2005. *Aristoxenus of Tarentum and the Birth of Musicology*. New York.

Gorteman, Claire. 1957. "Médecins de cour dans l'Égypte du III^{e} siècle avant J.-C.," *Chronique d'Égypte* 32: 313-36.

Green, Peter. 1993. *Alexander to Actium: The Historical Evolution of the Hellenistic Age*. 2nd ed. Berkeley.

Grenfell, B.P. and A.S. Hunt. 1903. *The Oxyrhynchus Papyri*. Vol 3. London.

Griffiths, Frederick. 1979. *Theocritus at Court*. Leiden.

Hacking, Ian. 1988. "The Participant Irrealist At Large in the Laboratory," *The British Journal for the Philosophy of Science* 39.3: 277-294.

--------. 1999. *The Social Construction of What?* Cambridge MA.

--------. 2002. "Making Up People," in *Historical Ontology*. Cambridge MA. 99-114.

Hankinson, R.J. 1991. *Galen on the Therapeutic Method: Books I and II*. Oxford.

--------. 1998a. *Cause and Explanation in Ancient Greek Thought*. Oxford.

--------. 1998b. *Galen: On Antecedent Causes*. Cambridge.

--------. 2008. "The Man and His Work," in *The Cambridge Companion to Galen*. R.J. Hankinson *ed*. Cambridge. 1-33.

Harding, Phillip. 2006. *Didymos on Demosthenes*. Oxford.

Hardy, G.H. 2000. *A Mathematician's Apology*. Cambridge.

Hart, Roger. 1999. "Beyond Science and Civilization: A Post-Needham Critique," *East Asian Science, Technology, and Medicine* 16: 88-114.

Heiberg, J.L. 1879. *Quaestiones Archimedeae: Inest de Arenae Numero Libellus*. Hauniae.

--------. 1910, 1913, 1915. *Archimedis opera omnia, cum commentariis Eutocii*. 3 vol. 2nd ed. Leipzig.

Heiberg, J.L. and H.G. Zeuthen. 1907. "Eine neue Schrift des Archimedes," *Bibliotheca Mathematica*[3] 7: 321-363.

Herman, Gabriel. 1997. "The Court Society of the Hellenistic Age," in *Hellenistic Constructs: Essays in Culture, History, and Historiography*. P. Cartledge, P. Garnsey, and E. Gruen *eds*. Berkeley. 199-224.

Hinds, Stephen. 1998. *Allusion and Intertext: The Dynamics of Appropriation in Roman Poetry*. Cambridge.

Jardine, Nick. 2003. "Whigs and Stories: Herbert Butterfield and the Historiography of Science," *History of Science* 43.2: 125-140.

Jones, Alexander. 1986. *Pappus of Alexandria: Book 7 of the Collection*. New York.

Keyser, Paul and Georgia Irby-Massie *eds*. 2008. *Encyclopedia of Ancient Natural Scientists: The Greek Tradition and its Many Heirs*. Hoboken.

Kidd, Ian. 1988. *Posidonius: II. The Commentary: (i) Testimonia and Fragments 1-149*. Cambridge.

Knobloch, Eberhard. 2000. "Archimedes, Kepler, and Guldin: the role of proof and analogy." in *Mathesis: Festschrift zum siebzigsten Geburtstag von Matthias Schramm*. R. Thiele *ed*. Berlin. 82-100.

Knorr, Wilbur Richard. 1986. *The Ancient Tradition of Geometric Problems*. Boston.

--------. 1989. *Textual Studies in Ancient and Medieval Geometry*. Boston.

--------. 1996. "The Method of Indivisibles in Ancient Geometry," in *Vita Mathematica: Historical Research and Integration with Teaching*. R. Calinger *ed*. Washington. 67-86.

--------. 2004. "The Impact of Modern Mathematics on Ancient Mathematics," in *Classics in the History of Greek Mathematics*. J. Christianidis *ed*. Dordrecht. 243-253.

Koyré, Alexandre. 1948. "Du monde de l'à peu près à l'univers de la precision" *Critique* 4.28: 806-33.

Kollesch, Jutta and Fridolf Kudlien. 1965. *Apollonios von Kition: Kommentar zu Hippokrates Über das Einrenken der Gelenke*. CMG 11.1.1. Berlin.

Kudlien, Fridolf. 1962. "Poseidonius und die Ärzteschule der Pneumatiker," *Hermes* 90.4: 419-29.

--------. 1972. "Zeuxis (7)" *RE* 2.19: col. 386-7.

Kuhn, Thomas. 1996. *The Structure of Scientific Revolutions*. 3rd ed. Chicago.

Kümmel, W. 1977. *Musik und Medizin: Ihre Wechselbeziehung in Theorie und Praxis von 800 bis 1800*. Freiburg.

Kuriyama, Shigehisa. 1999. *The Expressiveness of the Body and the Divergence of Greek and Chinese Medicine*. New York.

Landels, J.G. 1979. "Water-clocks and time measurement in Classical Antiquity," *Endeavour* 3.1: 32-37.

Lang, Phillipa. 2004. "Medical and Ethnic Identities in Ptolemaic Egypt," *Apeiron* 37.4: 107-31.

Langslow, D.R. 2000. *Medical Latin in the Roman Empire*. Oxford.

Latour, Bruno. 1987. *Science in Action: How to Follow Scientists and Engineers Through Society*. Harvard.

--------. 1988. *The Pasteurization of France*. Harvard.

--------. 1993. *We Have Never Been Modern*. Harvard.

--------. 2005. *Reassembling the Social*. Oxford.

Latour, Bruno and Steve Woolgar. 1986. *Laboratory Life: The Construction of Scientific Facts*. 2nd ed. Princeton.

Law, John. 2009. "Actor-Network Theory and Material Semiotics," in *The New Blackwell Companion to Social Theory*. 3rd ed. New York. 141-158.

Law, John and John Hassard *eds*. 1999. *Actor Network Theory and After*. Oxford.

Lenoir, Timothy. 1994. "Was the Last Turn the Right Turn? The Semiotic Turn and A.J. Greimas," *Configurations* 2.1: 119-136.

--------. 1998. “Inscription Practices and Materialities of Communication” in *Inscribing Science: Scientific Texts and the Materiality of Communication*. T. Lenoir *ed*. Stanford. 1-19.

Lennox, James. 1985. “Aristotle, Galileo, and the ‘Mixed Sciences’,” in *Reinterpreting Galileo*. W. Wallace *ed*. Washington, D.C. 29-51.

--------. 1998. “Review: Roger French *Ancient Natural History*,” *International Journal of the Classical Tradition* 4.3: 470-2.

Levene, David. 2010. *Livy’s Hannibalic War*. Oxford.

Lloyd, G.E.R. 1979. *Magic, Reason and Experience: Studies in the Origin and Development of Greek Science*. Cambridge.

--------. 1983. *Science, Folklore and Ideology: Studies in the Life Sciences in Ancient Greece*. Cambridge.

--------. 1987. *The Revolutions of Wisdom: Studies in the Claims and Practice of Ancient Greek Science*. Cambridge.

--------. 1990. *Demystifying Mentalities*. Cambridge.

--------. 1991a. “Experiment in Early Greek Philosophy and Medicine,” in *Methods and Problems in Greek Science*. Cambridge. 70-99.

--------. 1991b. “The Invention of Nature” in *Methods and Problems in Greek Science*. Cambridge. 417-434.

--------. 1992. “Methods and Problems in the History of Ancient Science: The Greek Case,” *Isis* 83.4: 564-77.

--------. 1996. *Authorities and Adversaries*. Cambridge.

--------. 2002. *The Ambitions of Curiosity: Understanding the World in Ancient Greece and China*. Cambridge.

Lloyd, G.E.R. and Nathan Sivin. 2002. *The Way and the Word: Science and Medicine in Early China and Greece*. New Haven.

Longino, Helen. 2006. “The Social Dimensions of Scientific Knowledge” in *Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/scientific-knowledge-social/. Accessed 10.2.2010.

Lockwood, E.H. 1961. *A Book of Curves*. Cambridge.

Majno, Guido. 1975. *The Healing Hand: Man and Wound in the Ancient World*. Cambridge, MA.

Mallon, Ron. 2008. “Naturalistic Approches to Social Construction,” *Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/social-construction-naturalistic/. Accessed 10.2.2010.

Manfeld, Jaap. 1998. *Prolegomena Mathematica: From Apollonius of Perga to Late Neoplatonism*. Leiden.

Manning, Joseph. 2010. *The Last Pharaohs: Egypt under the Ptolemies, 306-30 BC*. Princeton.

Mastrocinque, Attilio. 1995. "Les médecins des Séleucides," in *Ancient Medicine in its Socio-Cultural Context*. Ph.J. van der Eijk, H.F.J. Horstmanshoff, P.H. Schrijvers *eds*. Leiden. 1: 143-51.

Mattern, Susan. 1999. "Physicians and the Roman Imperial Aristocracy: The Patronage of Therapeutics," *Bulletin for the History of Medicine* 73.1: 1-18.

Mudry, Philippe. 1982. *La préface du De Medicina de Celse*. Suisse.

Mueller, Ian. 1981. *Philosophy of Mathematics and Deductive Structure in Euclid's* Elements. Cambridge, MA.

Mugler, Charles. 1958. *Dictionnaire historique de la terminologie géométrique des Grecs*. Paris.

--------. 1971. *Archimède: Tome III: Des Corps flottants, Stomachion, La Méthode, Le Livre des Lemmes, Le Problem des bœufs*. Paris.

Netz, Reviel. 1999a. "Proclus' Division of the Mathematical Proposition into Parts: How and Why was it Formulated?" *CQ* 49: 282-303.

--------. 1999b. *The Shaping of Deduction in Greek Mathematics*. Cambridge, Cambridge University Press.

--------. 2000. "Why Did Greek Mathematicians *Publish* Their Analyses?" in *Ancient and Medieval Traditions in the Exact Sciences: Essays in Memory of Wilbur Knorr*. P. Suppes, J. Moravcsik, and H. Mendell *eds*. USA: 139-157.

--------. 2002. "Greek Mathematicians: A Group Picture," in *Science and Mathematics in Ancient Greek Culture*. C.J. Tuplin and T.E. Rihll *eds*. Oxford. 196-216.

--------. 2003. "The goal of Archimedes' Sand-Reckoner," *Apeiron* 36.4: 251-290.

--------. 2004a. *The Works of Archimedes: Translated into English, together with Eutocius' commentaries, with commentary, and critical edition of the diagrams. Vol. 1: The Two Books* On the Sphere and the Cylinder. Cambridge.

--------. 2004b. *The Transformation of Mathematics in the Early Mediterranean World: From Problem to Equations*. Cambridge.

--------. 2004c. "Eudemus of Rhodes, Hippocrates of Chios, and the Earliest Form of a Greek Mathematics text" *Centaurus* 46: 243-86.

--------. 2009a. *Ludic Proof: Greek Mathematics and the Alexandrian Aesthetic*. Cambridge.

---------. 2009b. “Imagination and Layered Ontology in Greek Mathematics,” *personal communication*.

Netz, Reviel et alii. 2008. *The Archimedes Palimpsest: Transcription of* Method. http://archimedespalimpsest.net/Supplemental/ArchimedesTranscriptions/Method. Accessed 3.17.2009.

Netz, Reviel and William Noel. 2007. *The Archimedes Codex: How a Medieval Prayer Book Is Revealing the True Genius of Antiquity’s Greatest Scientist*. Philadelphia.

Netz, Reviel, Ken Saito, and Natalie Tchernetska. 2001-02. “A New Reading of *Method* Proposition 14: Preliminary Evidence from the Archimedes Palimpsest,” *SCIAMVS* 2: 9-29, 3: 109-125.

Netz, Reviel, Fabio Acerbi, and Nigel Wilson. 2004. “Towards a Reconstruction of Archimedes’ *Stomachion*,” *SCIAMVS* 5: 67-99.

Neugebauer, Otto and Richard Parker. 1969. *Egyptian Astronomical Texts*. 3 vols. Providence.

Nussbaum, Martha. 1994. *The Therapy of Desire: Theory and Practice in Hellenistic Ethics*. Princeton.

Nutton, Vivian. 1979. *Galen: On Prognosis: Edition, Translation, and Commentary*. CMG 5.8.1. Berlin.

--------. 2004. *Ancient Medicine*. London.

Palmieri, Paolo. 2008. “The Empirical Basis of Equilibrium: Mach, Vailiati, and the Lever,” *Studies in the History and Philosophy of Science* 39: 42-53.

Pearson, Lionel. 1991. *Aristoxenus Elementa Rhythmica: the Fragment of Book II and the Additional Evidence for Aristoxenean Rhythmic Theory*. Oxford.

Peremans, W. and E. van’t Dack. 1950-81. *Prosopographia Ptolemaica*. 9 vols. Louvain.

Pfeiffer, Rudolf. 1968. *History of Classical Scholarship: From the Beginnings to the End of the Hellenistic Age*. Oxford.

Pogo, A. 1936. “Egyptian Water-Clocks,” *Isis* 25: 403-25.

Polleichtner, Wolfgang. 2010. “Vorwart,” in *Livy and Intertextuality*. W. Polleichtner *ed*. Trier. 9-13.

Reinach, Théodore. 1907. “Un traité de géométrie inédit d’Archimède,” introduction de P. Painlevé, *Revue générale des sciences,* 30 nov. 911-928, 15 déc. 954-961.

Rheinberger, Hans-Jörg. 2010. *On Historicizing Epistemology: An Essay*. D. Fernbach *trans*. Stanford.

Riggsby, Andrew. 2006. *Caesar in Gaul and Rome: War in Words*. Austin.

Rufini, E. 1961. *Il "Metodo" di Archimede e le origini del calcolo infintesimale nell'antichità*. 2nd. ed. Milan.

Saito, Ken. 2006. "A preliminary study in the critical assessment of diagrams in Greek mathematical works," *SCIAMVS* 7: 81-144.

--------. 2009. "Reading Ancient Greek Mathematics," in *The Oxford Handbook of the History of Mathematics*. E. Robson and J. Stedall *eds*. Oxford. 801-26.

Samama, Évelyne. 2003. *Les médecins dans le monde grec: sources épigraphiques sur la naissance d'un corps médical*. Genève.

Sato, Tohru. 1986-87. "A Reconstruction of *The Method* Proposition 17, and the Development of Archimedes' Thought on Quadrature," *Historia Scientiarum* 31: 61-86, 32: 61-90.

Schiefsky, Mark. 2007. "Art and Nature in Ancient Mechanics," in *The Artificial and the Natural: An Evolving Polarity*. B. Bensaude-Vincent and W.R. Newman eds. Cambridge MA. 67-108.

Schöne, Hermann. 1896. *Apollonius von Kitium: Illustrierter Kommentar zu der Hippokrateischen Schrift* ΠΕΡΙ ΑΡΘΡΩΝ. Leipzig.

--------. 1907. "Marcellinus' Pulslehre: Ein Griechisches Anekdoton," in *Festschrift zur 49 Versammlung deutschen Philologen und Schulmänner*. Basel. 448-472.

Sefrin-Weis, Heike. 2010. *Pappus of Alexandria: Book 4 of the* Collection. London.

Sepp, Simon. 1893. *Pyrrhonëische Studien: Teil 1: Die Philosophische Richtung des Cornelius Celsus; Teil 2: Untersuchungen auf dem Gebiete der Skepsis*. Freising.

Shapin, Steven. 1992. "Discipline and bounding: The history and sociology of science as seen through the externalism-internalism debate," *History of Science* 30: 333-69.

--------. 1994. *A Social History of Truth: Civility and Science in Seventeenth Century England*. Chicago.

Shapin, Steven and Simon Schaffer. 1985. *Leviathan and the Air Pump: Hobbes, Boyle, and the Experimental Life*. Princeton.

Stephens, Susan. 2003. *Seeing Double: Intercultural Poetics in Ptolemaic Alexandria*. Berkeley.

Stok, Fabio. 1993. "La scuola medica Empirica a Roma. Problemi storici e prospettive di ricerca," *ANRW* 37.1: 600-45.

--------. 1994. "Celso i gli Empirici," in *La médecine de Celse: aspects historiques, scientifiques et littéraires*. G. Sabbah, Ph. Mudry, and B. Maire *eds*. Saint-Étienne. 63-75.

Thomas, Richard. 1986. "Virgil's *Georgics* and the Art of Reference" *HSCP* 90: 171-98.

Toomer, G.J. 1976. *Diocles: On Burning Mirrors*. Berlin.

Touwaide, Alain. 1992. “Les deux traits de toxicology attribués à Dioscoride: tradition manuscrite, établissement du texte et critique d’authenticité,” in *Tradizione e ecdotica dei testi medici tardoantichi e bizantini*. A. Garzya *ed*. Napoli. 291-335.

Tybjerg, Karin. 2005. “Hero of Alexandria’s Mechanical Treatises: Between Theory and Practice,” in *Physik-Mechanik: Geschichte der Mathematik und der Naturwissenschaften in der Antike*. A. Schürmann *ed*. 204-226.

van der Eijk, Philip. 2000. *Diocles of Carystus*. 2 vol. Leiden.

--------. 2005a. “Between the Hippocratics and the Alexandrians: Medicine, Philosophy and Science in the Fourth Century BCE” in *Philosophy and the Sciences in Antiquity*. W.R. Sharples *ed*. Aldershot.

--------. 2005b. *Medicine and Philosophy in Classical Antiquity*. Cambridge.

von Staden, Heinrich. 1975. “Experiment and Experience in Hellenistic Medicine,” *Bulletin for the Institute of Classical Studies* 22: 178-99.

--------. 1982. “Heresy and Hairesis: The case of the haireseis iatrikai,” in *Jewish and Christian Self-Definition III: Self-Definition in the Greco-Roman world*. B.F. Meyer and E.P. Sanders *eds*. London. 76-100, 199-206.

--------. 1989. *Herophilus: The Art of Medicine in Early Alexandria*. Cambridge.

--------. 1993. “Spiderwoman and the Chaste Tree: The Semantics of Matter,” *Configurations* 1.1: 23-56.

--------. 1994. “*Media quodammodo diuersas inter sententias*: Celsus, the ‘rationalists’, and Erasistratus,” in *La médecine de Celse: aspects historiques, scientifiques et littéraires*. G. Sabbah, Ph. Mudry, and B. Maire *eds*. Saint-Étienne. 77-101.

--------. 1996. “Body and Machine: Interactions between Medicine, Mechanics, and Philosophy in Early Alexandria” in *Alexandria and Alexandrianism*. P. Green *ed*. 85-106.

--------. 1997a. “Was Cassius an Empiricist?” in *Synodia: Studia humanitatis Antonio Garzya septuagenario dictata*. U. Criscuolo and R. Maisano *eds*. Napoli. 939-60.

--------. 1997b. “Teleology and Mechanism: Aristotelian Biology and Early Hellenistic Medicine,” in *Aristotelische Biologie: Intentionen, Methoden, Ergebnisse*. S. Föllinger and W. Kullmann *eds*. Stuttgart. 183-208.

--------. 1998. “Andréas de Caryste et Philon de Byzance” in *Sciences exactes et sciences appliquées à Alexandrie*. G. Argoud and J.-Y. Guillaumin *eds*. 147-172.

--------. 1999a. “Rupture and Continuity: Hellenistic Reflections on the History of Medicine,” in *Ancient Histories of Medicine: Essays in Medical Doxography and Historiography in Classical Antiquity*. Ph. van der Eijk *ed*. Leiden. 143-188.

--------. 1999b. “Celsus as Historian?” in *Ancient Histories of Medicine: Essays in Medical Doxography and Historiography in Classical Antiquity*. Ph. van der Eijk *ed*. Leiden. 251-294.

--------. 1999c. “Caelius Aurelianus and the Hellenistic Epoch: Erasistratus, the Empiricists and Herophilus,” in *La traité des Maladies aigués et des Maladies chroniques de Caelius Aurelianus: novelles approaches*. Ph. Mudry *ed*. 85-119.

--------. 2006. “Interpreting ‘Hippokrates’ in the 3rd and 2nd centuries BC,” in *Ärzte und ihre Interpreten: Medizinische Fachtexte der Antike als Forschungsgegenstand der Klassischen Philologie*. C.W. Müller, Ch. Borckmann, and C.-W. Brunschön *eds*. Leipzig. 15-47.

--------. 2007. “*Physis* and *Technē* in Greek Medicine,” in *The Artificial and the Natural: An Evolving Polarity*. B. Bensaude-Vincent and W.R. Newman *eds*. Cambridge MA. 21-49.

von Wilamowitz-Moellendorff, Ulrich. 1894. “Ein Weihgeschenk des Eratosthenes,” reprinted in *Kleine Schriften II* 1971: 48-70. Berlin.

--------. 1924. *Hellenistische Dichtung*. 2 vols. Berlin.

Wellmann, Maximilian. 1895. *Die Pneumatische Schule bis auf Archigenes*. Berlin.

--------. 1908. *Philumeni De Venenatis Animalibus Eorumque Remediis*. CMG 10.1.1. Berlin.

--------.1930. “Beiträge zur Geschichte der Medizin im Altertum,” *Hermes* 65.3: 322-31.

West, M.L. 1973. *Textual Criticism and Editorial Technique Applicable to Greek and Latin Texts*. Stuttgart.

--------. 1992. *Ancient Greek Music*. Oxford.

White, Stephen. 2007. “Posidonius and Stoics Physics,” *Bulletin of the Institute for Classical Studies*, suppl. vol. 94: *Greek and Roman Philosophy 100 BC to 200 AD*. R. Sorabji and R.W. Sharples *eds*. 35-76.

Whitmarsh, Tim. 2001. *Greek Literature and the Roman Empire: The Politics of Imitation*. Oxford.

Wickkiser, Bronwen. 2008. *Asklepios, Medicine, and the Politics of Healing in Fifth-Century Greece*. Baltimore.

Willi, Andreas. 2003. *The Languages of Aristophanes*. Oxford.

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